ALLEN, HAGEDORN & HERRCKE

The Effect of Superheat and Pressure on the Steam Consumption of a Corliss Engine

Mechanical Engineering

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THE EFFECT OF SUPERHEAT AND PRESSURE ON THE STEAM CONSUMPTION OF A CORLISS ENGINE

BY

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FREDERICK ARTHUR HAGEDORN
ERNEST ARTHUR HERRCKE

THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

MECHANICAL ENGINEERING

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

1911

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May 29 1911

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George B. Allen
Frederick Arthur Hagedorn
Ernest Arthur Sterricker

ENTITLED The Effect of Superheat and Pressure on the Steam Consumption of a Corliss Engine

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Mechanical Engineering

Instructor in Charge.

APPROVED: G. A. Goodenough

Acting HEAD OF DEPARTMENT OF Mechanical Engineering

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The Effect of Superheat and Pressure on the Steam Consumption of a Corliss Engine.

Object

The object is to determine the effect of superheat and pressure on the steam consumption of a 12 inch x 24 inch Corliss engine, running non-condensing.

Introduction

A number of tests were run a year ago on the Corliss engine in the Mechanical Engineering Laboratory with saturated steam at pressures varying from 60 to 140 lb. Throughout the series of tests, the speed was constant at a bout 120 R.P.M. and the load was varied from no load to the maximum load the engine would carry at the pressures chosen. For this thesis it was desired to conduct a similar series of tests using steam superheated to 500° Fahr. at the superheater, and compare these results with those obtained with saturated steam. It was also desired to determine the effect of condensing on the steam consumption with superheated steam.

During the preliminary tests poor lubrication prevented successful operation, but, when a better grade of lubricant

was substituted, the engine ran very satisfactorily.

Description of Apparatus

The apparatus used consisted of a simple Corliss engine, an Edison bipolar direct current generator, a water rheostat, a Worthington surface condenser with Worthington circulating and Blake vacuum pumps, and a Foster superheater. The instruments used in connection with the apparatus consisted of two Crosby inside spring indicators, three steam gages, seven thermometers, a continuous speed counter, a voltmeter, two ammeters, a tank and scales.

The engine, manufactured by the Allis Chalmers Co. of Milwaukee, Wisconsin, is of the double eccentric simple Corliss type. The principal dimensions and constants of this engine are given on page 14, and photographs of it may be found on pages 44 & 45.

The Edison bipolar direct current generator, which is belt driven, has a rating of 100 kilowatts at 140 volts. The field is separately excited from a 220 volt line, and any desired excitation may be maintained by means of a rheostat in series with the field.

The most convenient method of absorbing the generated power is by means of a water rheostat which consists of three water tight barrels filled with salted water. In each barrel are placed two iron plates which are attached to the terminals of the circuit. The lower plate is firmly fixed near the bottom

of the barrel. The upper plate which was made the positive terminal is attached by means of a flexible rope to a hole in a long shaft extending over all the barrels. Each rope is of such length as to prevent the plates from coming in contact when at the lowest position. A hand wheel and a worm are fastened to a shaft hung directly under the long shaft. This worm actuates a worm wheel keyed to the long shaft. By turning the hand wheel each rope, attached to an upper plate, is wound up on the long shaft. Thus the resistance of the external circuit can be adjusted for any desired load.

The terminals from each barrel are connected in parallel to the generator line at the switchboard. A diagram of connections is shown on page 48, and a photograph on page shows the general arrangement.

The Foster superheater, separately fired, is rated at 4500 lb. of steam per hour, superheated 200° Fahrenheit and is built for a pressure of 150 lb. per square inch. This superheater, manufactured by the Power Specialty Co. of New York, is made up of elements, each of which consists of two steel tubes, one inside the other and so connected that the steam from the boiler passes thru the annular space between the tubes, the inner tube being closed at both ends. Cast iron tapering discs shrunk on the outer tube increase the heating surface and prolong the life of the tubes.

The Worthington condenser, manufactured by H.R.Worthington Co., is mounted above the wet-air and circulating pumps. It is of the "double flow" surface type and has a cool-

ing surface of 362 sq.ft. The condensing water is circulated thru a number of brass tubes by a 6 in. x 9 in. x 10 in. Worthington piston circulating pump. The exhaust steam enters at the top and comes in contact with the outer surface of these tubes. The condensed steam falls to the bottom of the condenser and with the entrained air is removed by a 6 in. x 9 in. x 10 in. Blake wet-air piston pump. A tank of suitable size placed on a platform scale near the condenser receives the condensed steam.

Experimental Methods

The first work done after all the apparatus had been assembled was to calibrate accurately each instrument to be used. The method of testing in each case was in accordance with commonly accepted practice.

The aim throughout the tests was to keep all conditions as nearly constant as possible. This extreme caution was necessary in order that the results of this test could be compared with a similar set of tests run, a year before, under the same conditions with saturated steam.

Fig. 15 shows the graphical log for one test in which the conditions were fairly representative of the whole series. It wil be noted that the temperatures of the superheater and the circulating water were the only ones which showed any considerable variation. The variations of the circulating water temperatures had no effect on the results obtained. The temperature of the superheater depended altogether on the personal equation

of hand firing and under such conditions, variations are to be expected. It must be noticed however that the temperatures of the steam in the steam pipe and in the steam chest were very constant, not being affected appreciably by any change in the superheater. This constancy was no doubt due to the heat capacity of the walls of the steam pipe; i.e. the excess heat at the higher temperatures at the superheater were absorbed by the pipe and when the temperature at the superheater decreased the pipe gave back heat to the steam.

The pressure was controlled, by hand, by the manipulation of a gate valve on the steam main before the steam entered the superheater. The pressure at this valve was kept about 2 lbs. higher than at the steam chest in order to compensate for the line pressure drop.

The temperature of the steam was controlled by adjusting the draft at the superheater, the rate of combustion determining the degree of superheat.

On account of the construction of this engine and also on account of the high loads to be carried it was deemed advisable to use some method of loading other than friction brakes or dynamometers. The method used was to belt the engine to a direct current generator which in turn was loaded by means of a water rheostat. The connections and arrangement of these pieces of apparatus are shown in the photograph page 44 . The upper positive plates, being connected by means of ropes to a single shaft, could be lowered or raised at will, thus increasing or decreasing the load. The B.H.P. for each load was obtained

by subtracting the friction H.P. from the actual load on the generator; the friction horse-power was obtained from a curve determined by tests the year before.

In order to keep the back pressure of the steam cylinder at that of the atmosphere a slight vacuum was maintained in the condenser except when a test was run on an 18 inch vacuum. At frequent intervals the condenser was tested for leakage; this was done by running it for a half hour during which time about 1/2 lb. of water leaked out. This amount was too small to affect any results and hence was disregarded.

Another experimental feature was the determination of leakage with saturated steam. The engine was run until thoroughly hot. After shutting down, the cylinder head was removed and the head end valve blocked shut so that any steam leaking by the piston, while the engine was running, was readily detected. The escape of the steam was so small as to be negligible and hence it can be said that the piston was practically tight.

Next the engine was blocked and the valve mechanism so arranged that both steam valves were shut. Steam was then admitted to the steam chest under full pressure until the chest and valves were hot. The steam was then shut off and by observing how long it took for the pressure to drop to that of the atmosphere an idea was obtained as to how tight the valves were. The H.E. steam valve was absolutely tight and C.E. steam valve was fairly tight. The same procedure was gone through with the other valves. The exhaust valves were fairly tight since it took about 5 minutes for the pressure to drop to that of the

atmosphere.

Superheated steam shows however less leakage than saturated steam because there is less condensate in the former case to leak through than in the case with saturated steam.

Discussion of Results

The graphical log on page 15 is fairly representative and was run under the following conditions: gage pressure of 100 lb.; steam temperature of 500° F.; 120 R.P.M.; and a load of 52 K.W. on the generator. The conditions of this test were exceptionally constant and show the degree of uniformity that was maintained. The extreme variation in steam pressure amounted to 3 lb. or less than 2 percent from the average value. The drop in pressure from the valve in the steam amin where the pressure was controlled to the receiver apparently varied from 2 to 6 lb. The actual instantaneous variation,however, probably never amounted to more than 1 or 2 lb. at most. The large variation in recorded values was due to inability to get readings at both places at the same instant, and as it was impossible to keep the pressure perfectly constant by hand throttling, it often happened that there would be a small change in pressure during the time taken to obtain the two readings.

Some trouble was experienced in keeping the temperature of the steam at the superheater at exactly 500° on account of the difficulty in controlling the fire to suit the demand, altho less trouble was experienced at the higher loads. This

temperature of 500° F. was maintained thruout all the superheat experiments so that the degree of superheat was less at the highest pressure than at the lowest. The extreme variation in the test shown on page 15 is only 7° F., but in a few tests this variation was as much as 10° F.

The temperature variation at the superheater did not affect the variation at the engine to the same degree because of the large heat capacity effect of the comparatively long steam pipe. The maximum variation at the throttle was 1° F. from the average value, while that at the steam chest was 2° F.

The load was adjusted by means of the water rheostat, and was kept within a maximum variation of 1 1/2 K.W. from the average value, this variation being less than 3 percent. Due to the relative constancy of the conditions maintained, the M.E.P. shown by the indicator cards has a maximum variation from the average of only 4 percent.

On pages 16 to 20 are plotted the I.H.P. - water rate curves showing the steam consumption for eachgroup of tests at the same pressure. The relative steam consumption with both saturated and superheated steam is well shown by these curves. For example, taking the group at 100 lb. pressure, we find at 50 H.P. or 3/4 load, that the water ra te with saturated steam is 32 1/2 lb. while with superheated steam, under the same conditions of operation, the rate is 26 1/4 lb. This shows a saving in water rate of 6 1/4 lb. or 19.2 percent. At 80 H.P. the water rate with saturated steam is 32 1/4 lb., while the superheat value is 25 1/4 lb., representing a saving of 7 lb. or 21.7 per-

cent. These results show that the percent saving in water rate is greater at higher loads.

With saturated steam at all pressures the water rate becomes a minimum and then increases as an economical point is passed. This turning point of economical capacity is present in all similar types of engines using saturated steam and ordinarily at about 75 percent of the maximum capacity. We notice with superheated steam that not only is the water rate considerably less than with saturated steam, but that the saving is greatest at the heaviest possible loads, showing that the most economical point occurs at a higher load than corresponding point on the saturated curve. In the case of superheated steam it is seen that the point of minimum water rate occurs at 90 percent of the greatest possible load. This condition resulting from the use of superheated steam means more than a substantial saving in water rate; it shows that while it was not economical to operated beyond the rated load with saturated steam it is possible to run economically at the greatest possible capacity with superheated steam.

It was planned to run a series of tests using a 28 inch vacuum with superheated steam, but owing to air leakage of the pipe system it was impossible to get a vacuum greater than 18 inches, at which the series was run. The water rate curve for this condition of operation shows that the saving in water rate over the non-condensing superheated steam test is nearly a constant quantity, being somewhat less at the lower loads than at the higher ones. The curve obtained from the vacuum tests shows

that operating condensing gives flatter curves than when operating the same engine non-condensing.

Since it was impossible to obtain a 28 inch vacuum, an assumption was made to reduce the conditions to that vacuum. It was assumed that the saving of water rate was proportional to the vacuum and the values so obtained were plotted with the dotted points thru which a dotted curve was drawn as shown. Refering to the group of tests run at 120 lb. per sq. in. pressure, the water rate curves of which are plotted on page 19 , it is seen that the most economical load for saturated steam is about 70 H.P. with a water rate of 29 lb. The use of superheated steam reduced this rate, at the same load, to 25 lb., showing a saving of 4 lb. or 13.8 percent. Superheated steam operating with a vacuum of 18 inches gives a water rate of 21 1/4 lb. which is a saving of 7 3/4 lb. or 26.7 percent over saturated steam non-condensing. The assumption for a 28 inch vacuum with superheated steam brings the water rate down to 19 lb. showing a saving of 10 lb.,or 34.5 percent over saturated steam.

While the use of a 28 inch vacuum with superheated steam shows an apparent gain of 34.5 percent over saturated steam non-condensing it must be remembered that this is not net gain because from 5 to 10 percent of the saving must be used to run the pumps. The use of vacuum also entails extra capital expenditure and labor which further reduces this saving another 5 or 10 percent, so that the net saving due to the use of vacuum is probably not over 15 or 20 percent.

The water rate was also plotted on the basis of M.E.P.

and B.H.P. as shown on pages 21 to 30 . The form of these curves is similar to that of the water rate- I.H.P. series with the exception that the B.H.P. curves are all moved upward a small amount due to the friction H.P. of the engine. The discussion of the water rate - I.H.P. series applies in general to the curves drawn on the basis of M.E.P. and B.H.P.

It is well shown on pages 31 to 35 that the use of superheated steam causes a considerable increase in the potential efficiency of the engine. The reason for this increase is that the cylinder condensation is greatly reduced by the use of superheated steam, so that one of the largest losses due to the use of saturated steam has been greatly decreased.

At full load, the mechanical efficiency reaches a value of 95 percent, which is high for this type of engine.

The curves on page 41 give the degree of superheat for different rates of total steam supplied at the superheater, receiver and chest. The curve of superheat at the heater drops down somewhat at the heavy loads because the rated performance of the heater was slightly exceeded.

In spite of the fact that the degree of superheat at the heater is lower at high loads, there is a decided increase in the degree of superheat at the receiver and chest as the load is increased. This may be explained by considering the loss due to radiation between the superheater and throttle to be nearly constant in number of B.t.u. per sq.ft. of pipe surface per unit of time. On this assumption there will be a smaller loss per lb. of steam at the high velocities, thus leaving more heat

available at the throttle and consequently a higher degree of superheat. This fact shows that when using superheated steam, the velocity should be made as high as allowable for the pressure drop in the pipe because the smaller pipe required will expose less radiating surface and the high velocity will entail a smaller loss of superheat.

The minimum steam consumption under different conditions of operation are shown in table I. This table also gives the percent saving in steam consumption by increasing the gage pressure in increments of 20 lb. for both saturated and superheated steam, and the percent saving of superheated steam over the consumption with saturated steam at the same pressure.

Table 1.

Minimum Steam Consumption.

Pressure lb. per sq. in.	Saturated Steam	Superheated Steam	% saving by 20 lb. Increments.		% saving by use of superheated St.
			Sat. Steam	Sup. St.	
40	45.5	39.5	15.4	18.2	13.2
60	38.5	32.5	11.7	13.8	15.5
80	34.0	28.0	8.8	8.9	17.6
100	31.0	25.5	8.1	7.8	17.8
120	28.5	23.5	5.3	6.4	17.6
140	27.0	22.0	5.5	4.6	18.5
160	25.5	21.0			17.6

Conclusions.

The following is a summary of the results obtained from the above data and the conclusions that may be drawn from them:

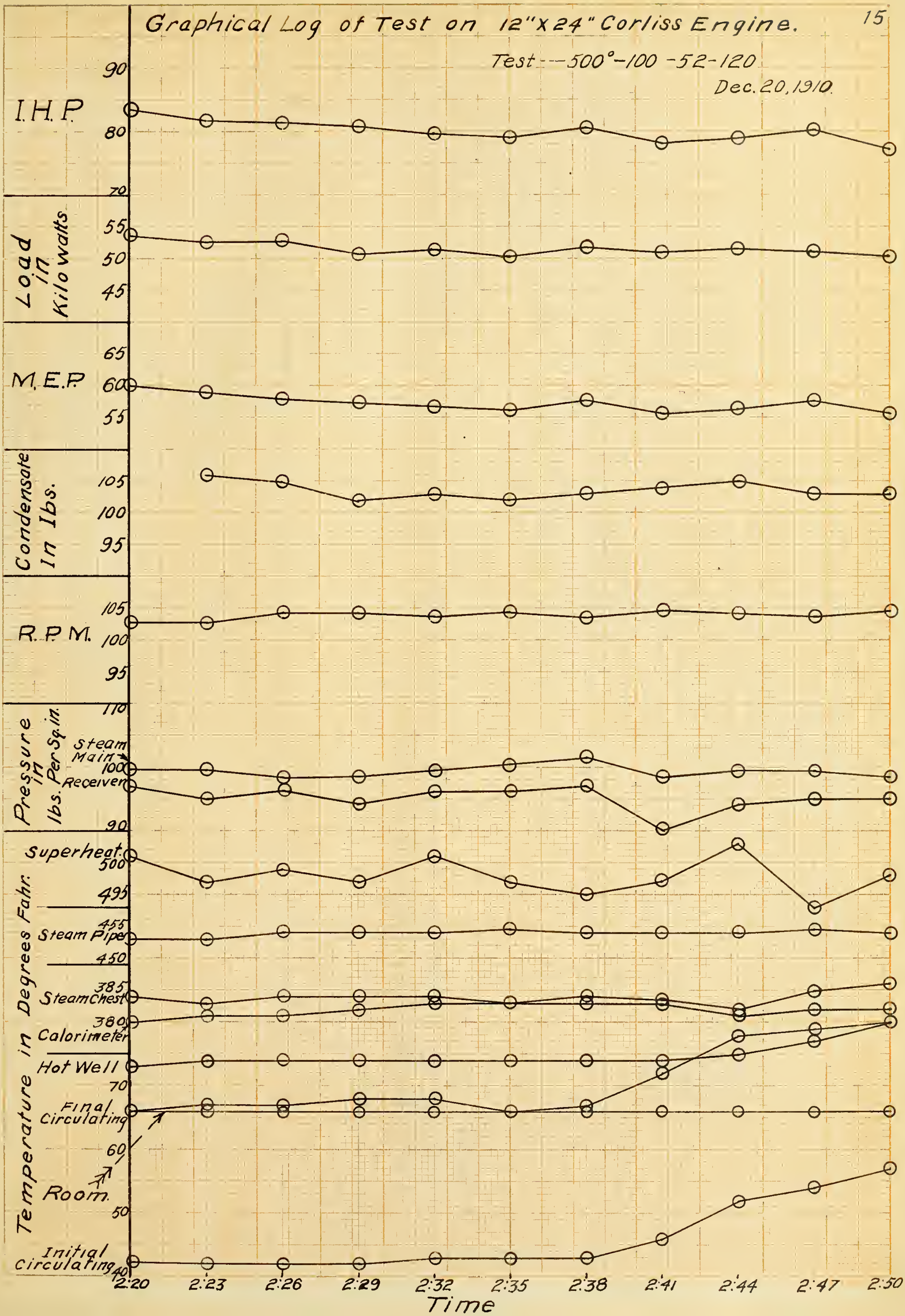
1. With use of superheated steam a lubricating oil with a higher flash point must be used, than for saturated steam.
2. It is advantageous to increase the rate of flow in superheated steam pipes in order to decrease the drop in superheat between the engine and the superheater.
3. Superheated steam increases the power of the engine and decreases the steam consumption per horse-power hour.
4. Superheated steam decreases the water rate with every increase of pressure within the range chosen.
5. At 140 lbs. pressure the engine shows the minimum water rate for both saturated and superheated steam : the saving due to superheat being 18.5 %.

GENERAL DIMENSIONS OF CORLISS ENGINE.

1. Engine made by............................Allis Chamers Co.
2. Usual R.P.M. is....................................60-140.
3. Usual boiler pressure.............................60-140.
4. Diameter of cylinder...............................12.02 in.
5. Clearance .........H.E.=7.89%.......C.E.= 7.04%.
6. Length of Stroke.....................................24 in.
7. Length of connecting rod..5ft.6in. Its cross-section round.
8. Ratio of crank to connecting rod is 1 to 5 1/2.
9. Area of bearing surface of cross head on guides is 78 sq. in.
10. Diameter of piston rod is.......................2 3/16 in,
11. Diameter of shaft in bearings is.................6 in.
12. Diameter of flywheel bore is........................7 in.
13. Diameter of belt pulley is..9 ft. Its face is...12 in.
14. Diameter of flywheel is...9 ft. Cross-section of rim32 sq.in
15. The velocity of flywheel rim is about 56.5 ft.p.s. at 120R.PM
16. Length of crank shaft bearing is15.5in. Outboard bearing 11 in
17. The number of valves affecting the steam distribution is 2.
18. The engine is

Horizontal	Single cylinder
Automatic cut-off	Not self contained
Running over	Double wrist plate
Non-condensing	Variable speed

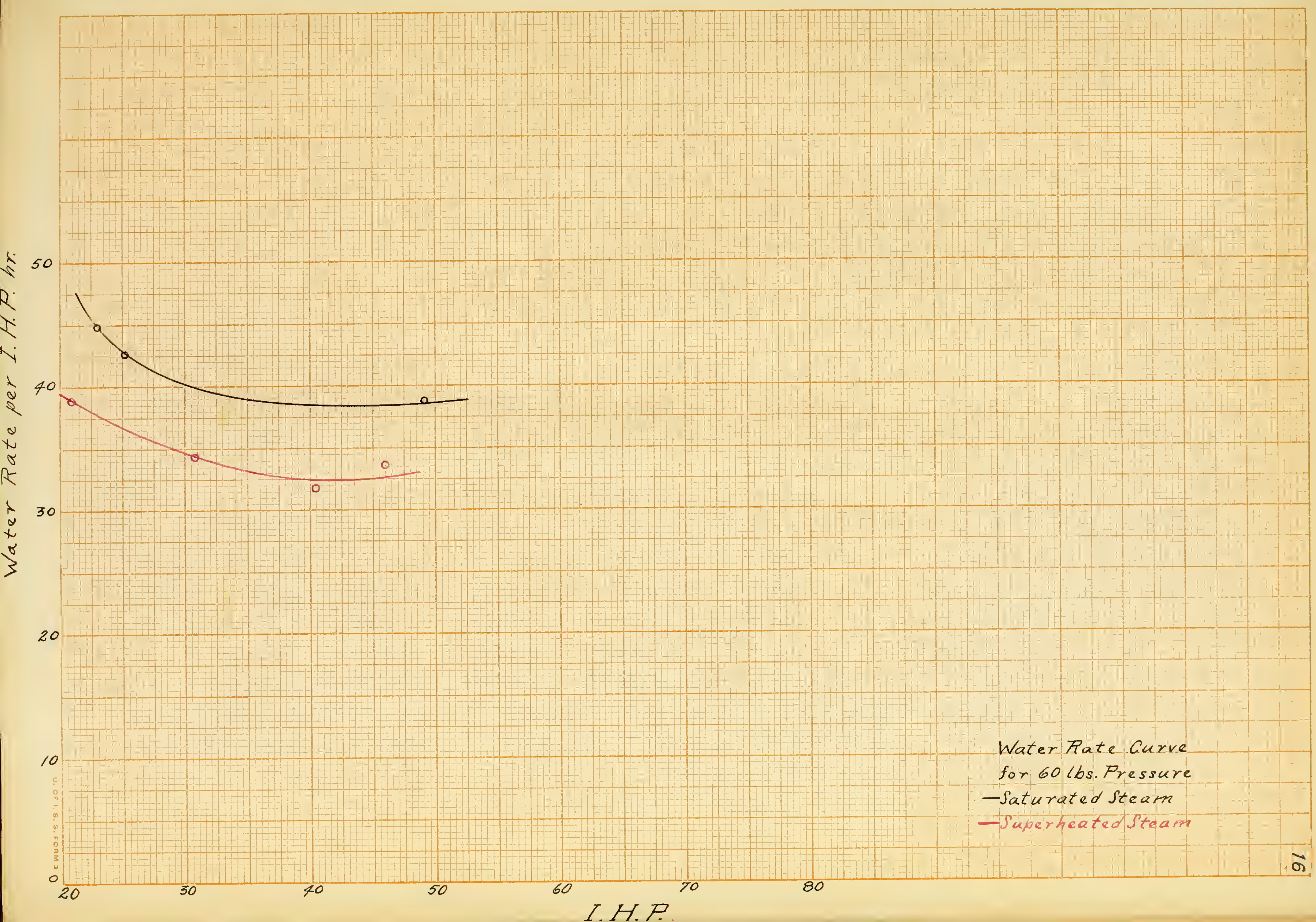
19. Engine constant is
    - H.E.= .00686
    - C.E.= .00665
20. Steam port area is.......................1 7/16in. by11 5/64in.



Graphical Log of Test on 12"x24" Corliss Engine.

Test---500°-100-52-120

Dec. 20, 1910.



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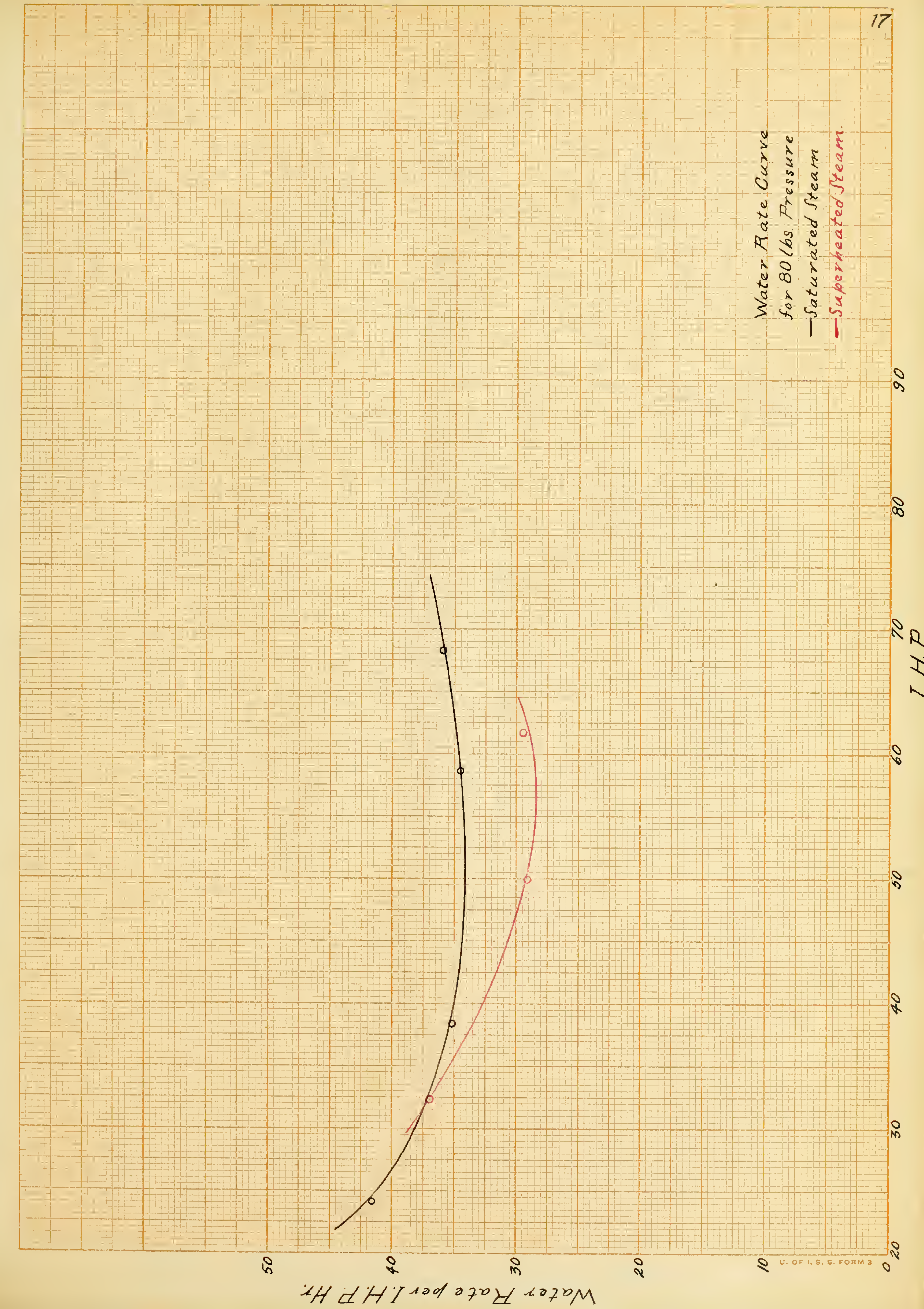
Water Rate Curve
for 80 lbs. Pressure
—Saturated Steam
—Superheated Steam.
I. H. P.
20
30
40
50
60
70
80
90
Water Rate per I.H.P. Hr.
0
10
20
30
40
50
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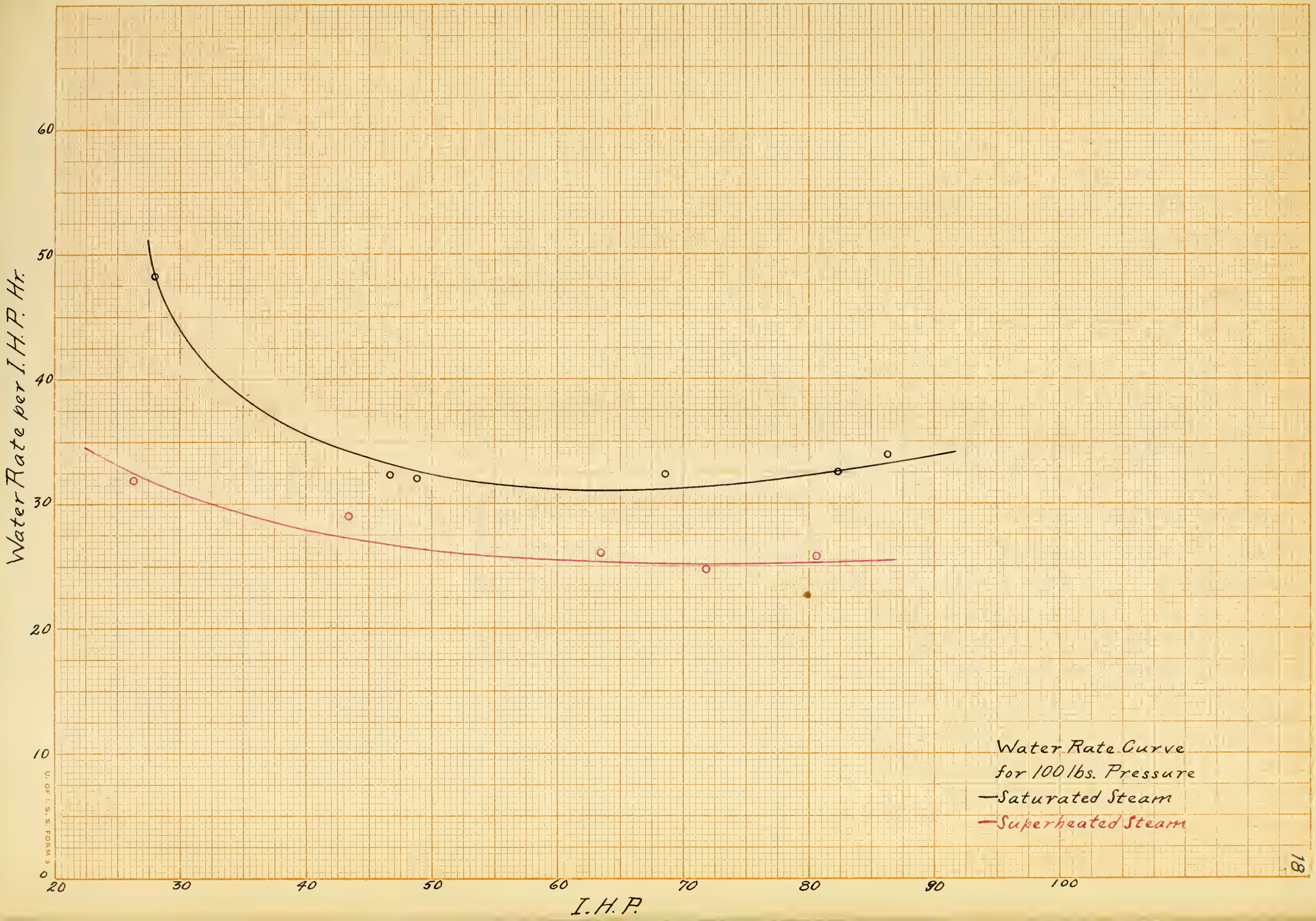

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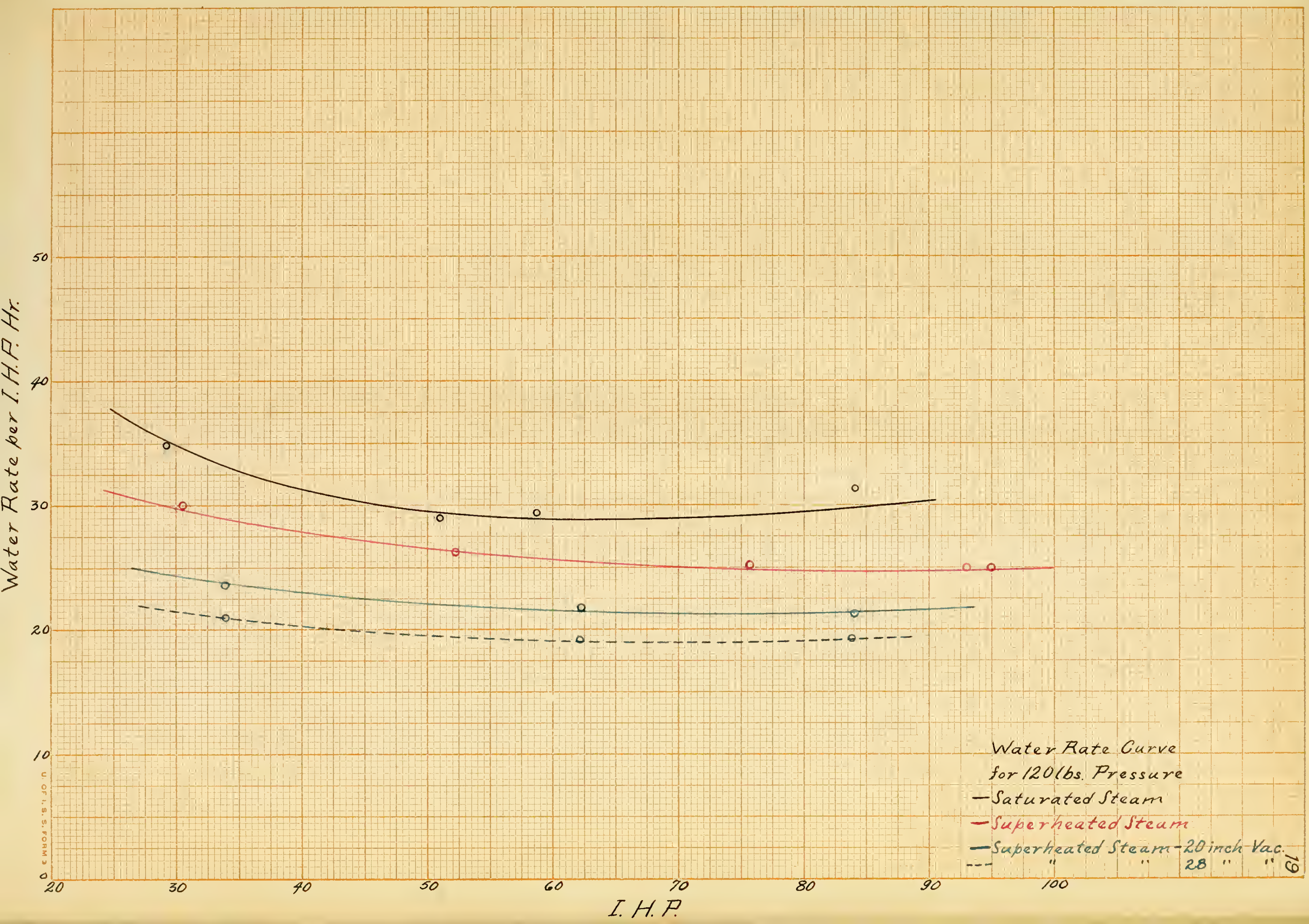

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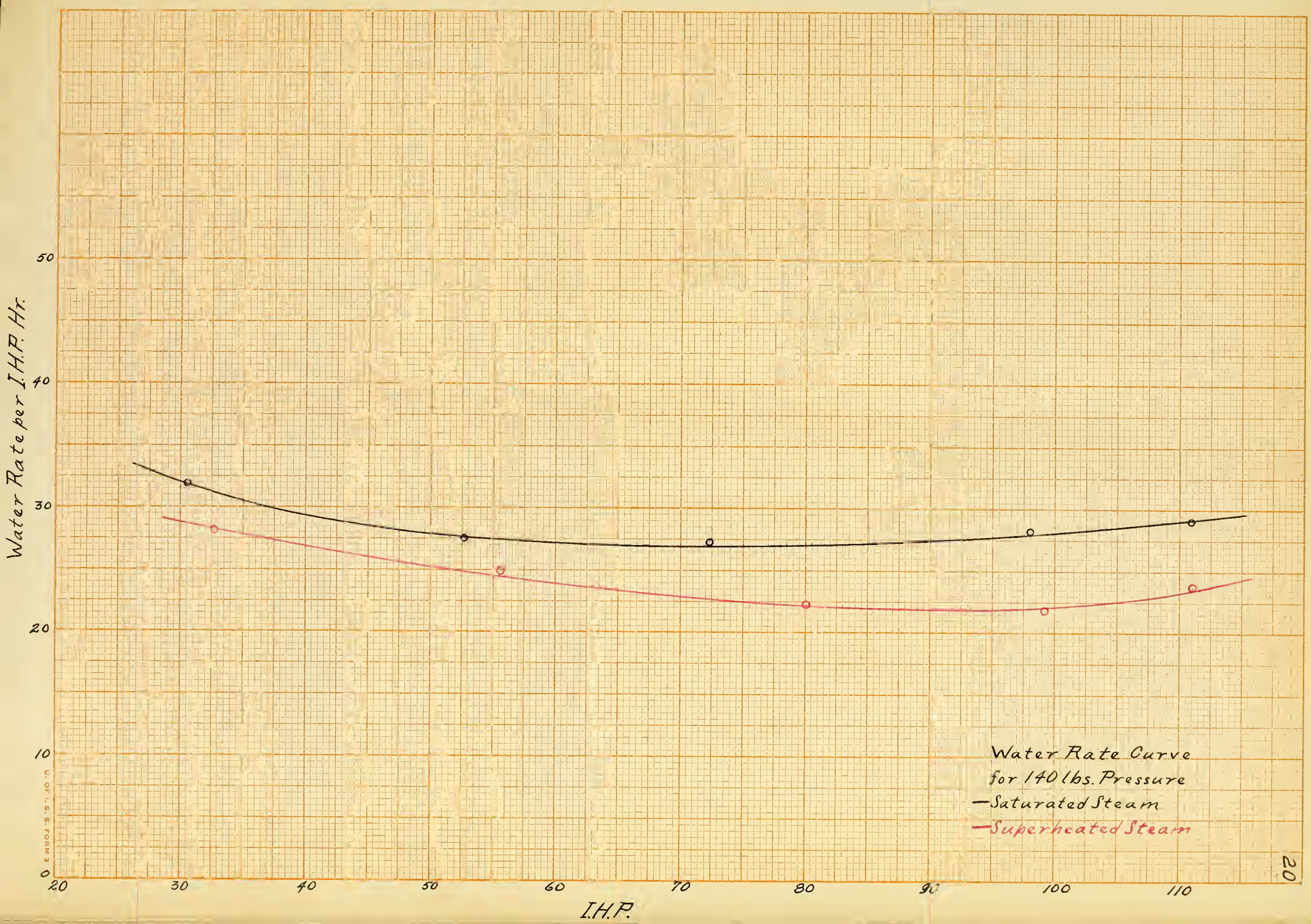

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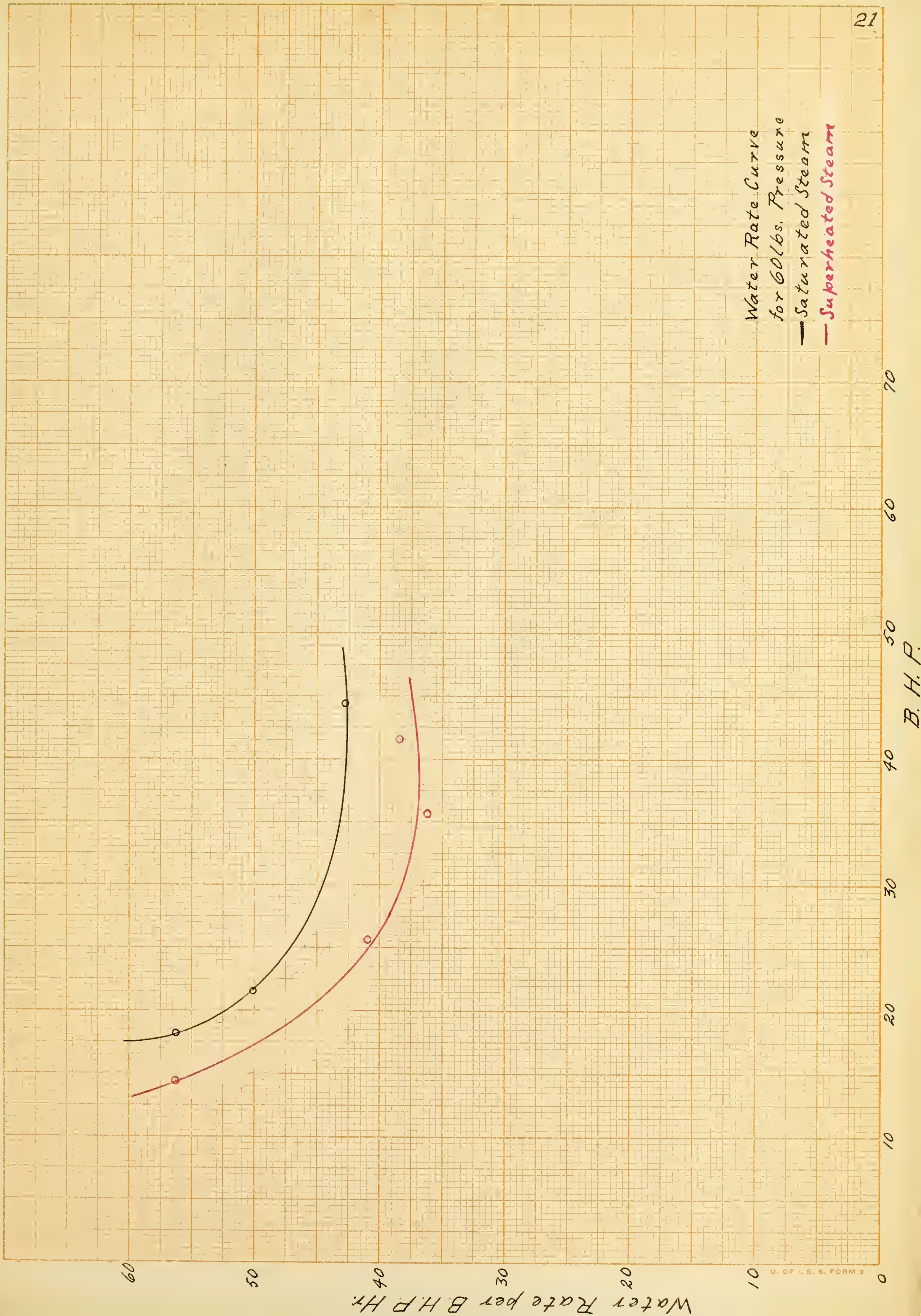
Water Rate Curve
for 60 lbs. Pressure
Saturated Steam
Superheated Steam
B. H. P.
0
10
20
30
40
50
60
70
Water Rate per B.H.P. Hr.
10
20
30
40
50
60
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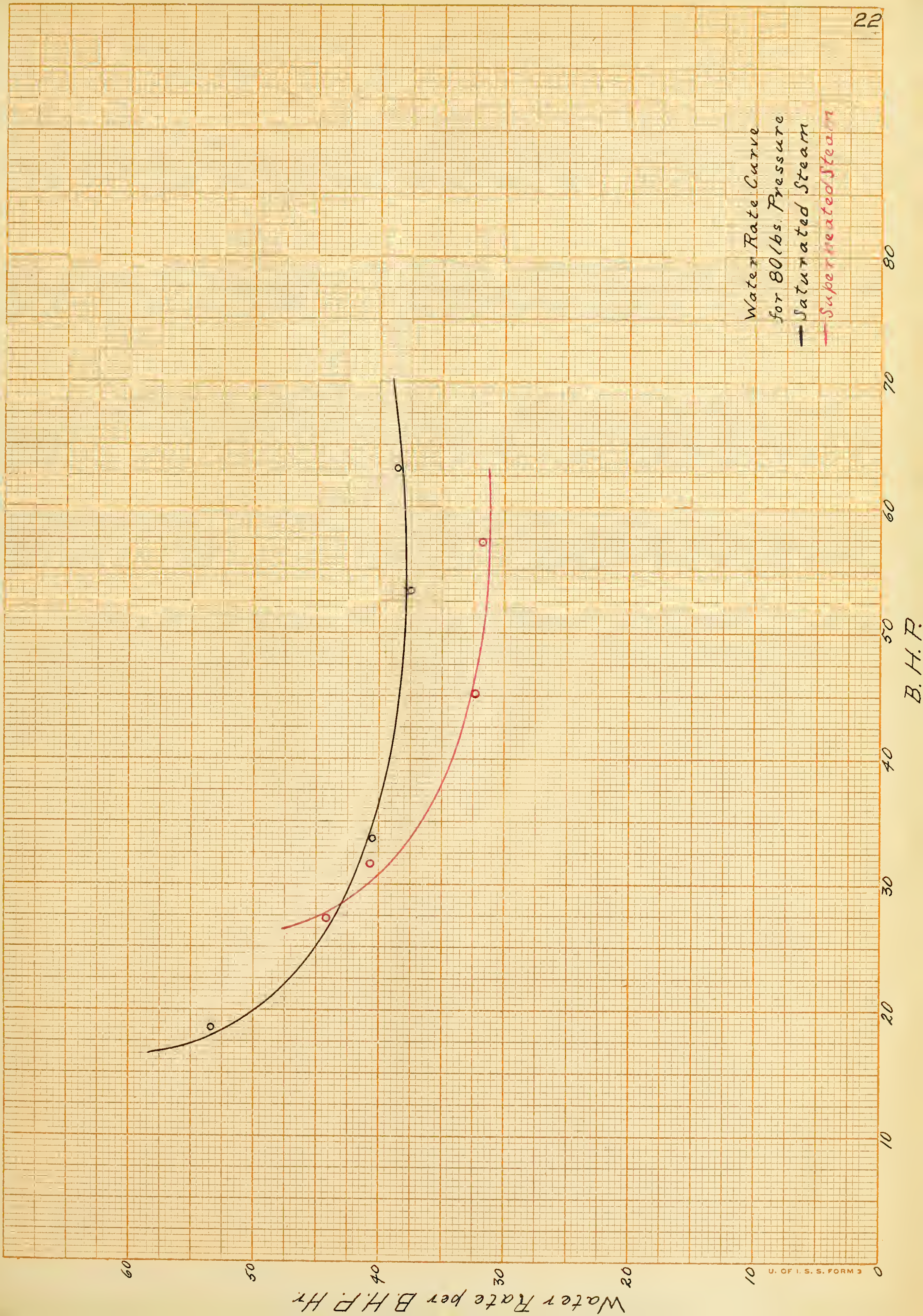

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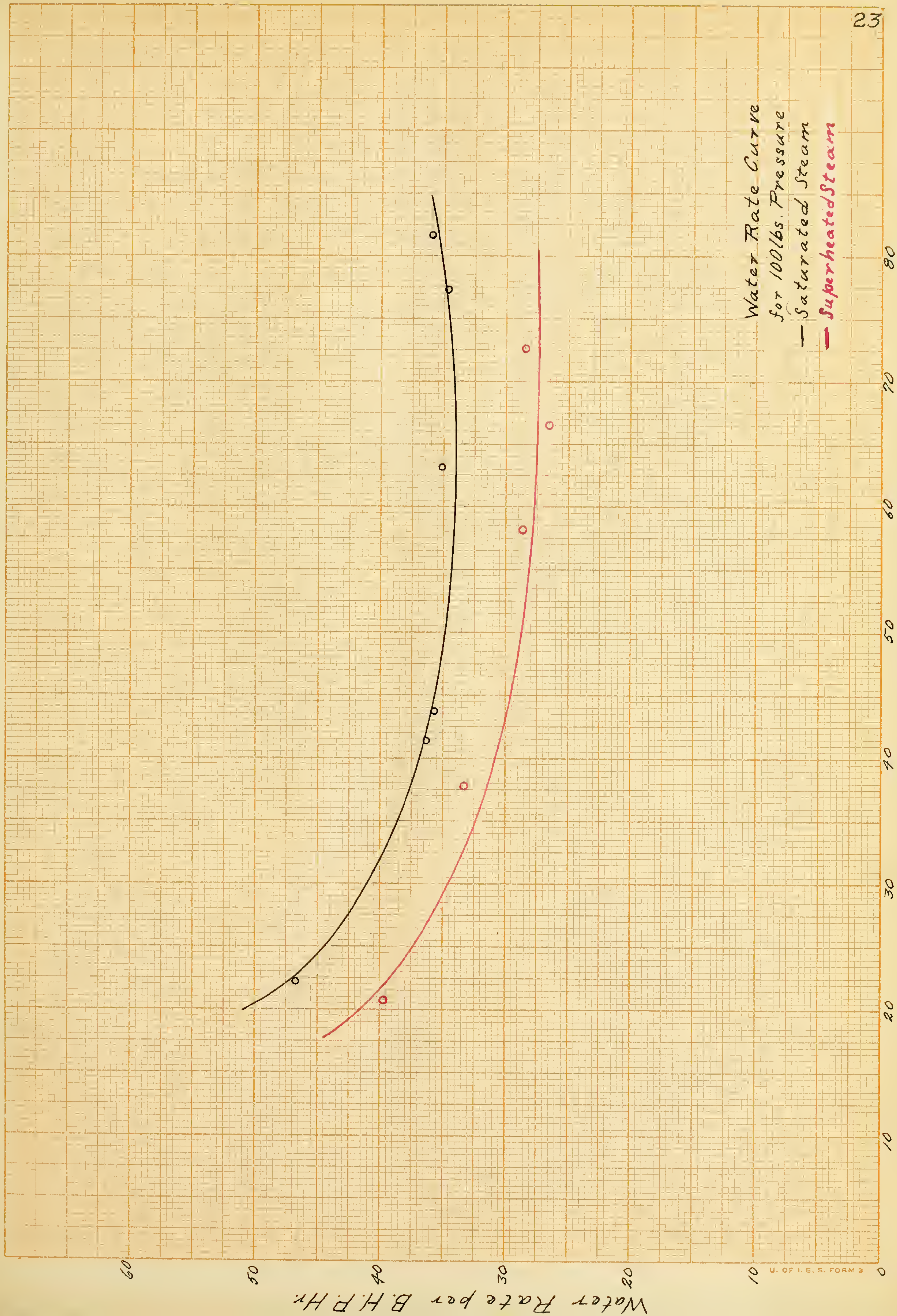
Water Rate Curve
for 100 lbs. Pressure
— Saturated Steam
— Superheated Steam
B. H. P.
0
10
20
30
40
50
60
70
80
Water Rate per B.H.P. Hr.
0
10
20
30
40
50
60
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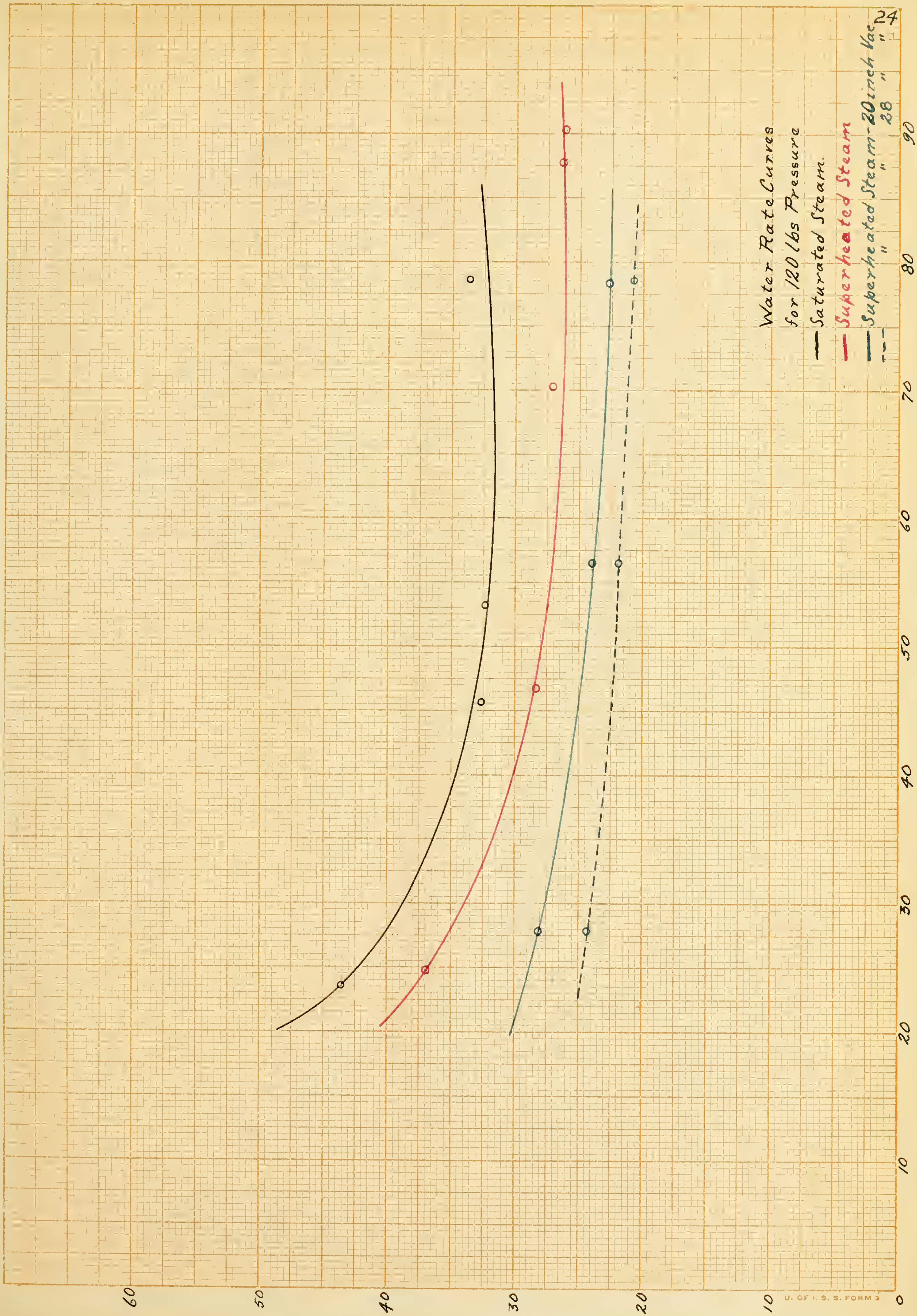

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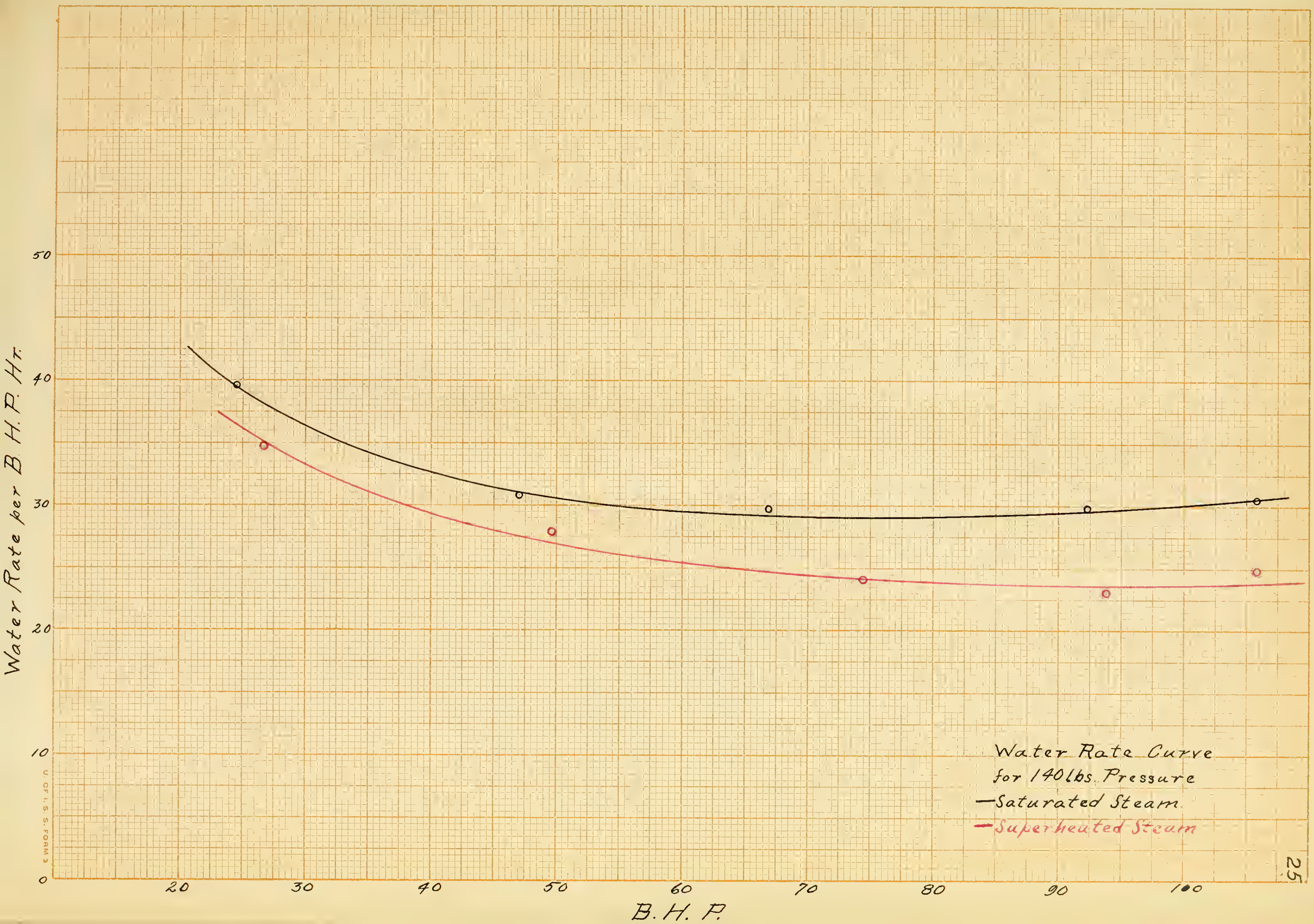

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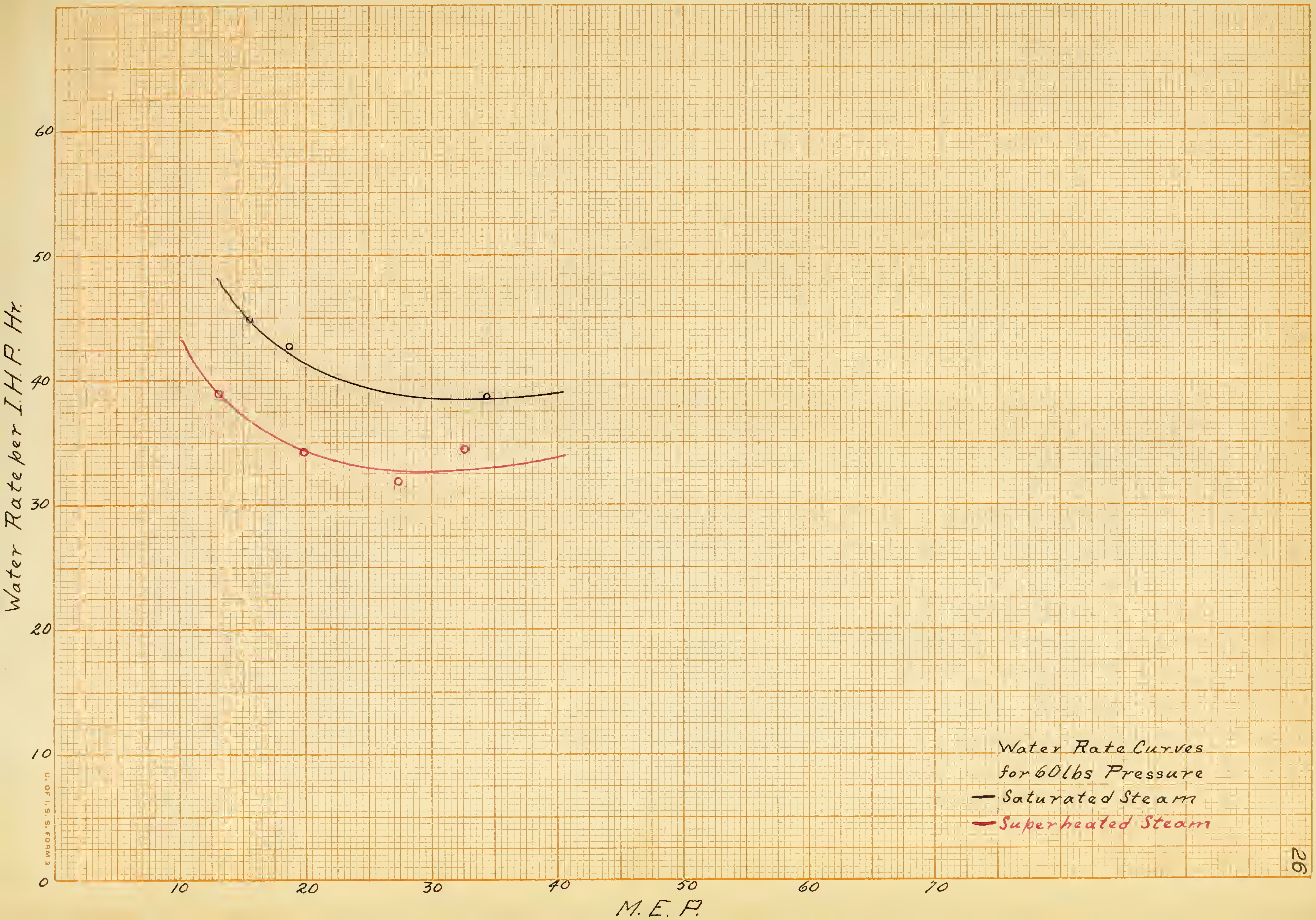

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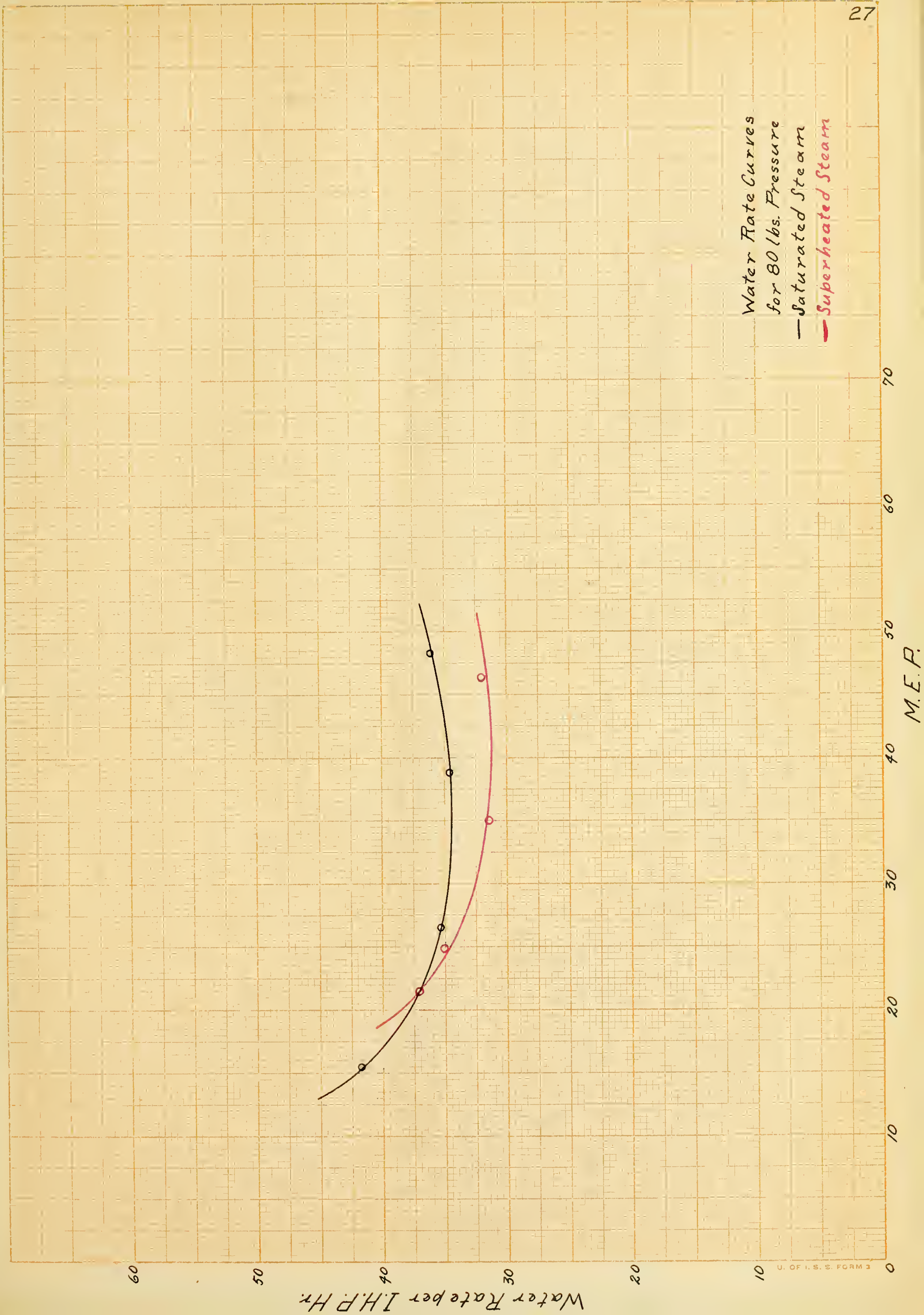
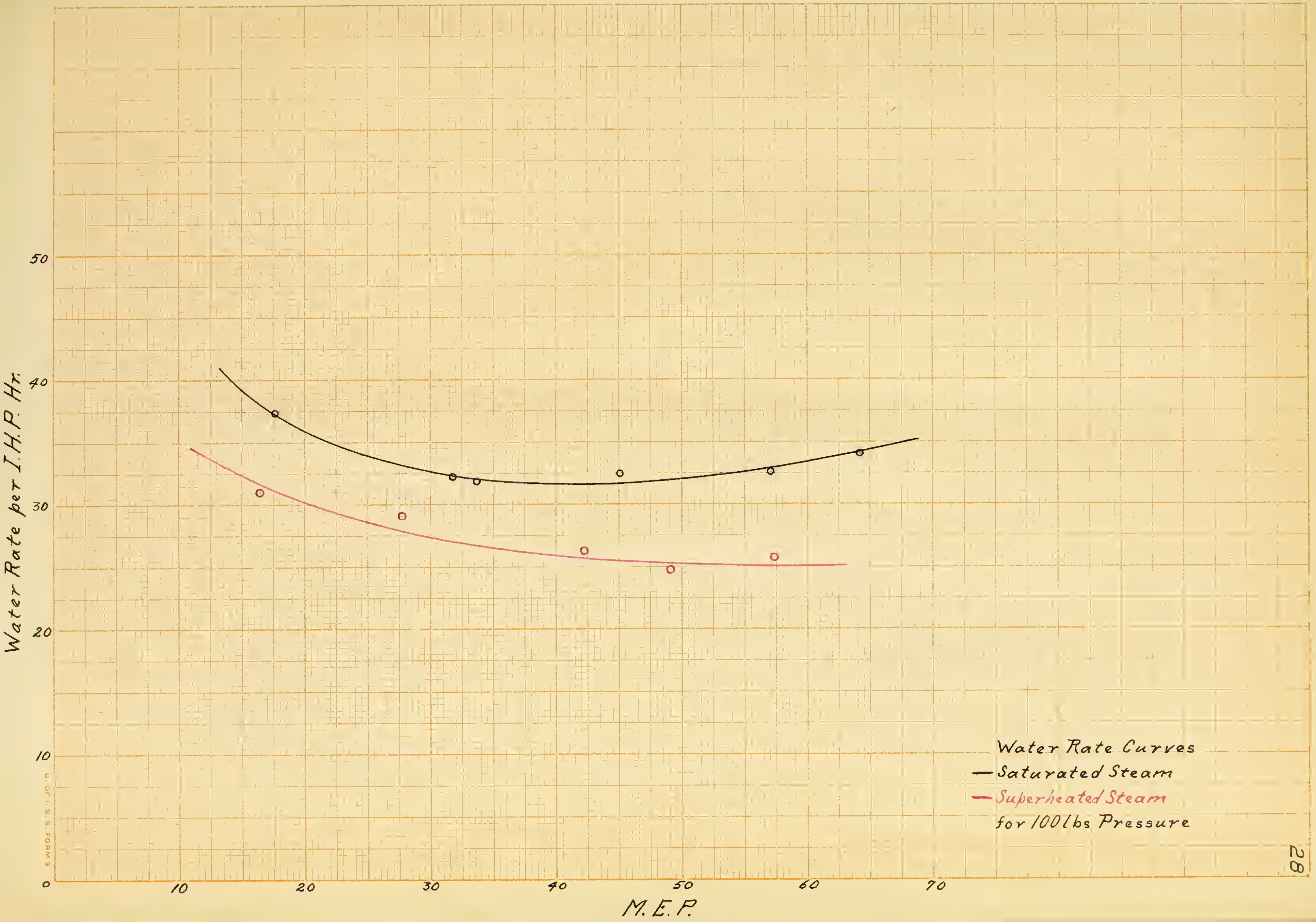

Water Rate Curves
for 80 lbs. Pressure
— Saturated Steam
— Superheated Steam
M.E.P.
0
10
20
30
40
50
60
70
Water Rate per I.H.P. Hr.
10
20
30
40
50
60
U. OF I. S. S. FORM 3



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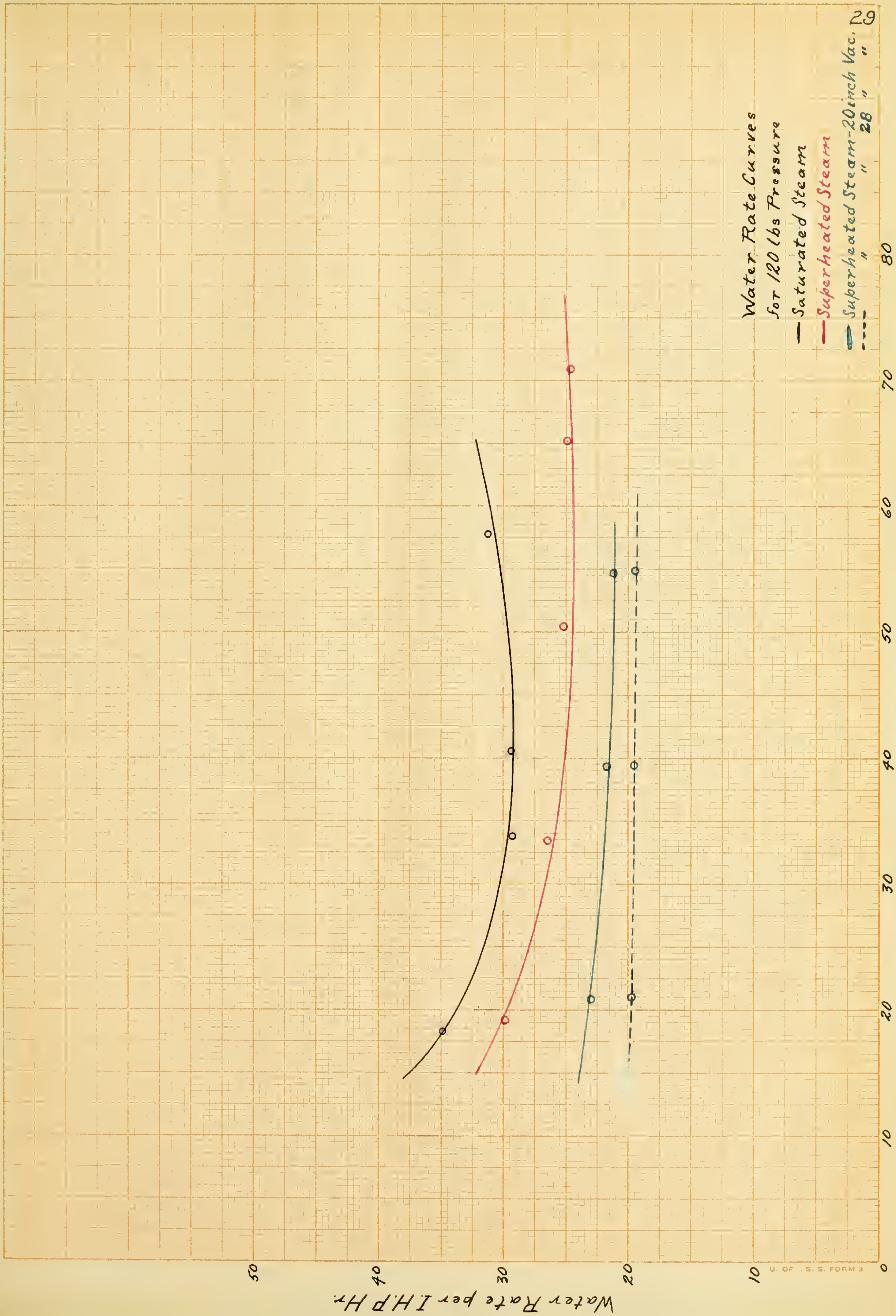

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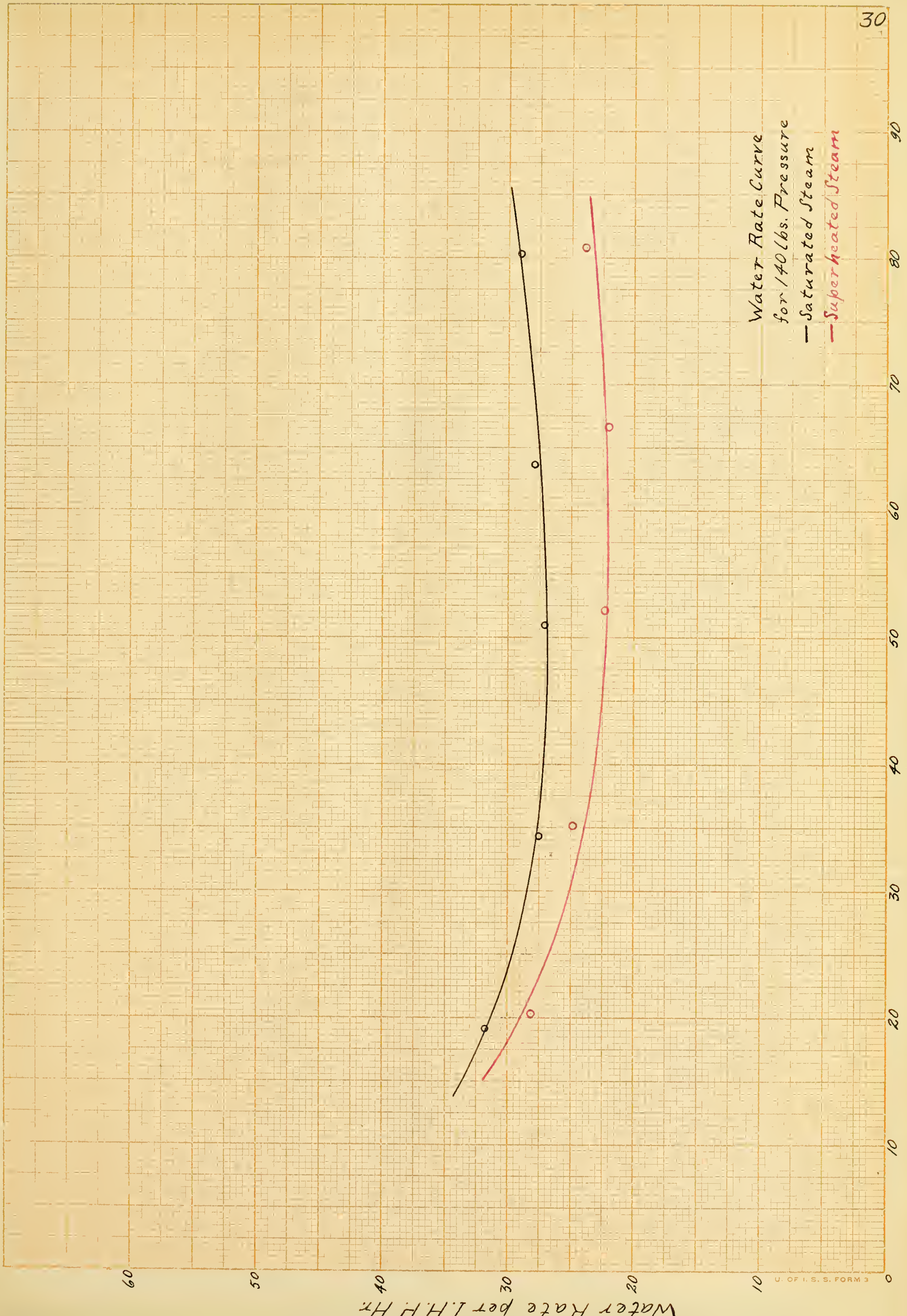
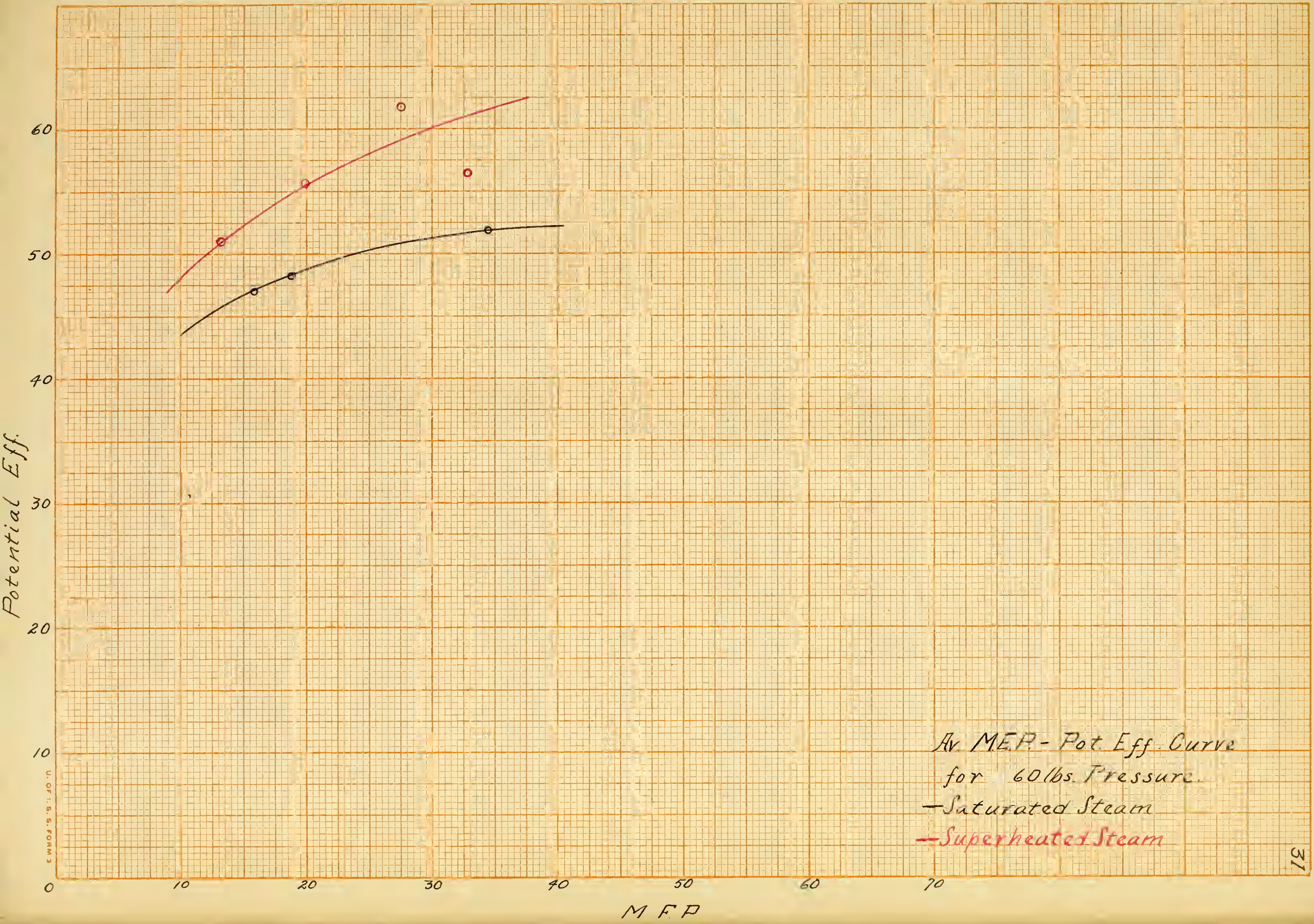

Water Rate Curve
for 140 lbs. Pressure
— Saturated Steam
— Superheated Steam
M.E.P.
0
10
20
30
40
50
60
70
80
90
Water Rate per I.H.P. Hr.
60
50
40
30
20
10
0
U. OF I. S. S. FORM 3



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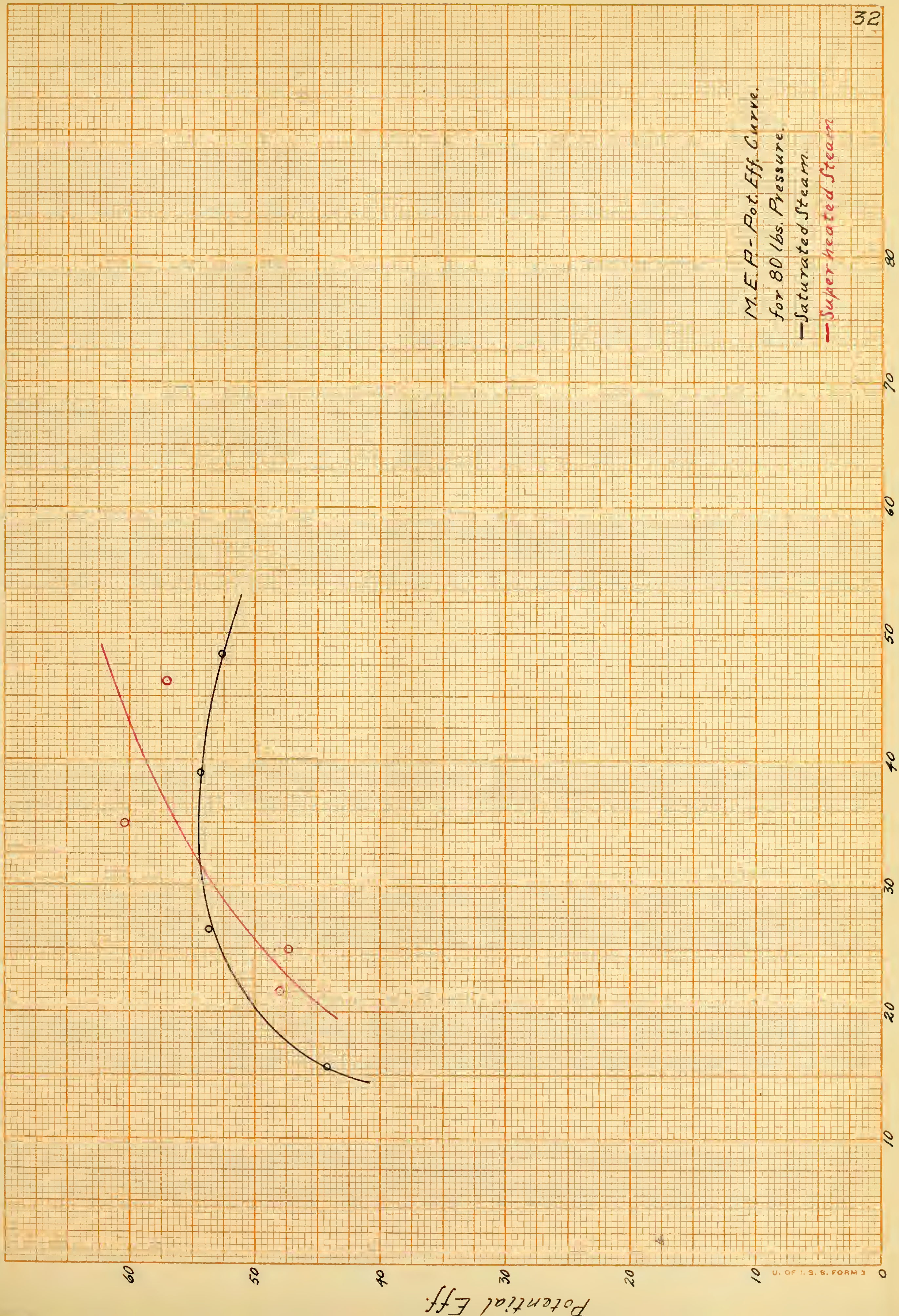
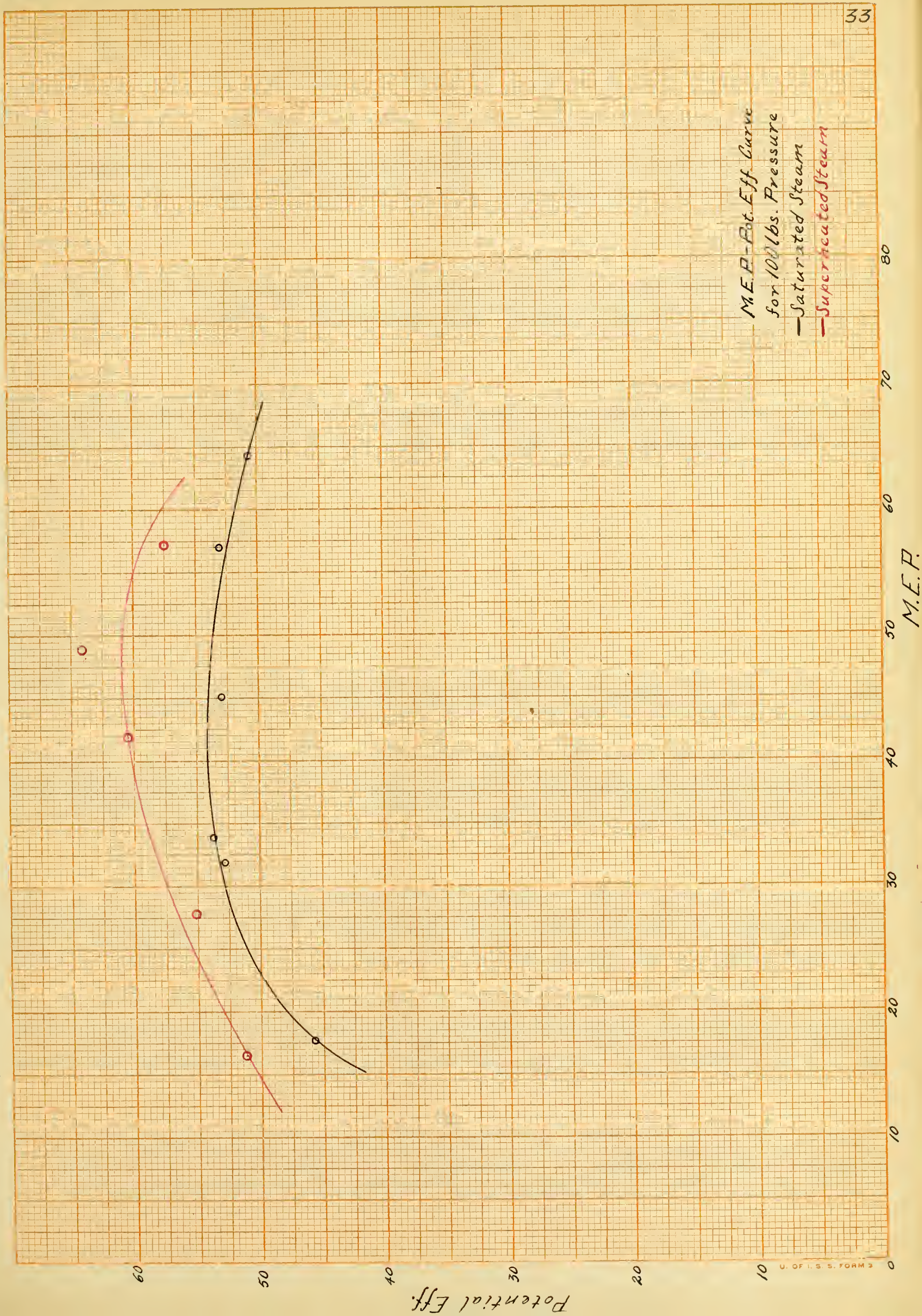
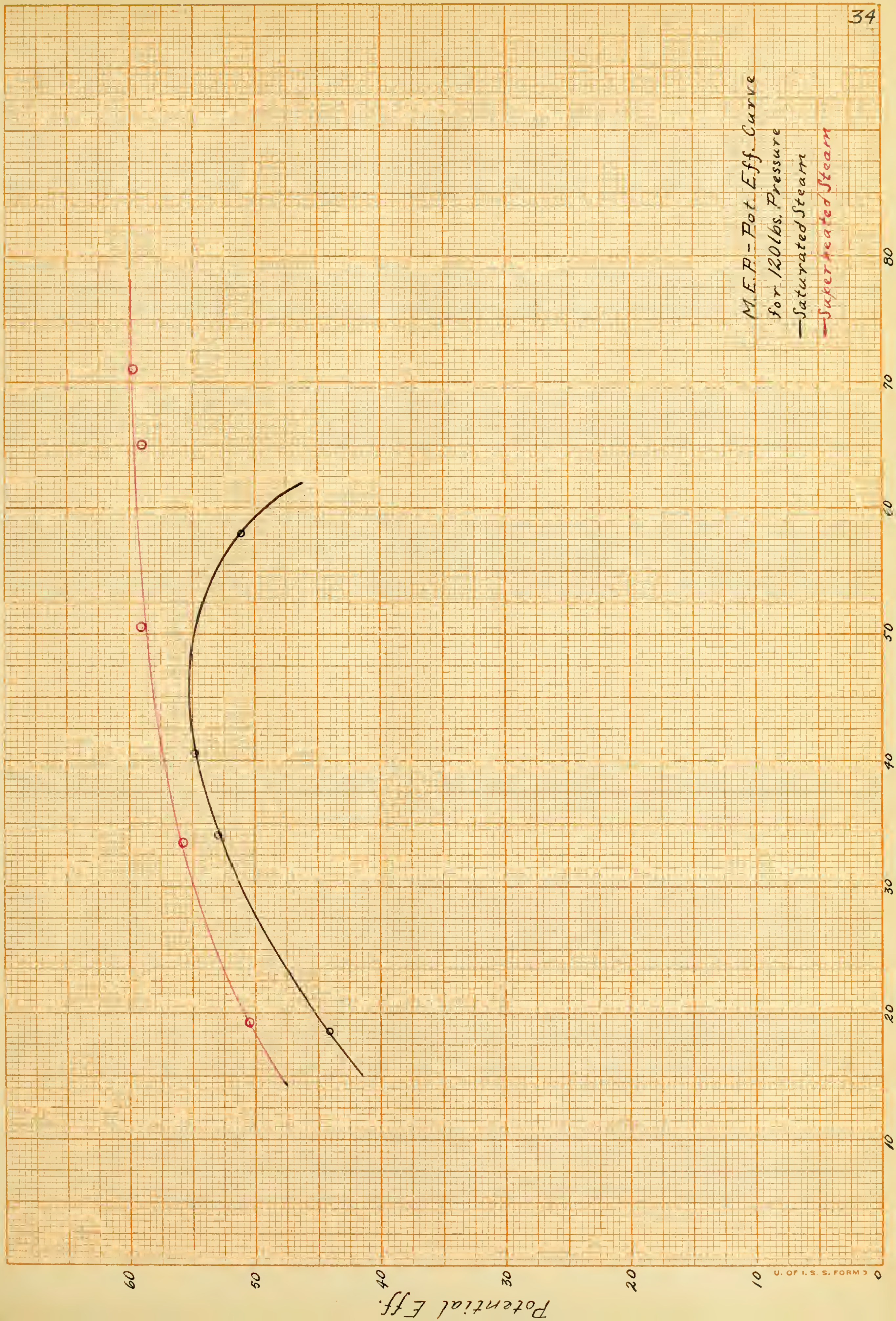
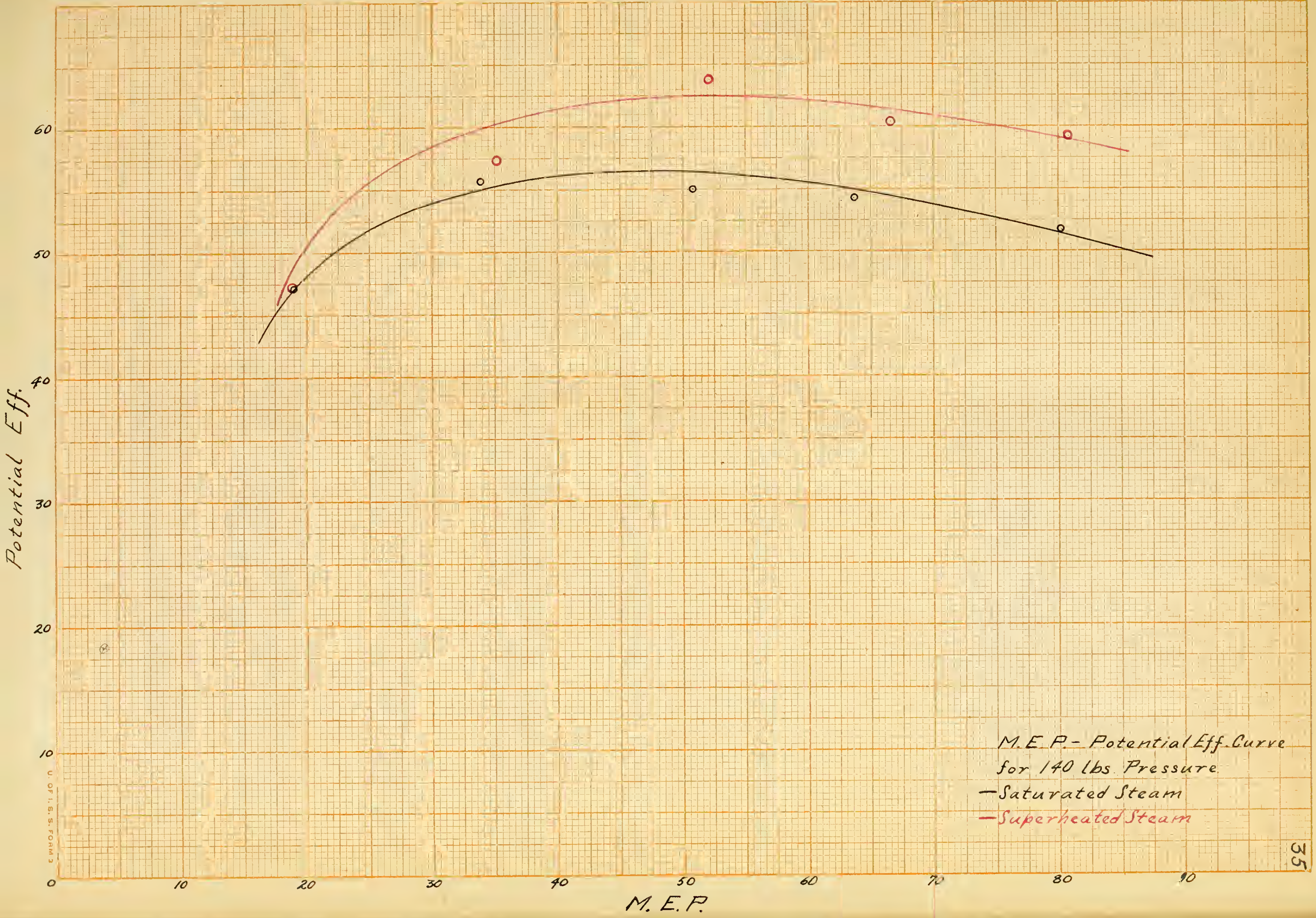
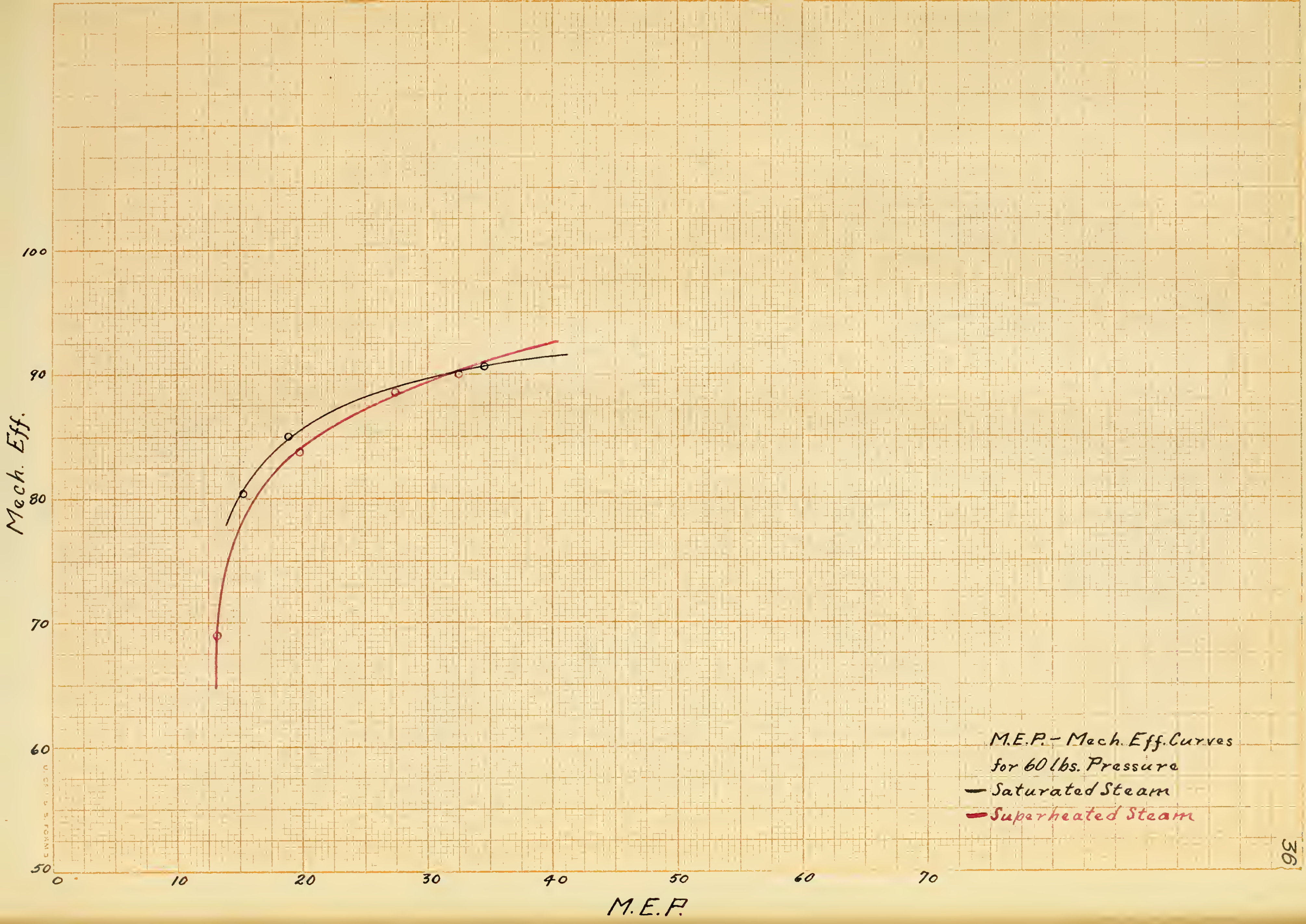

M.E.P.-Pot. Eff. Curve.
for 80 lbs. Pressure.
—Saturated Steam.
—Super heated Steam
M.E.P.
Potential Eff.
0
10
20
30
40
50
60
70
80
10
20
30
40
50
60
U. OF I. S. S. FORM 3

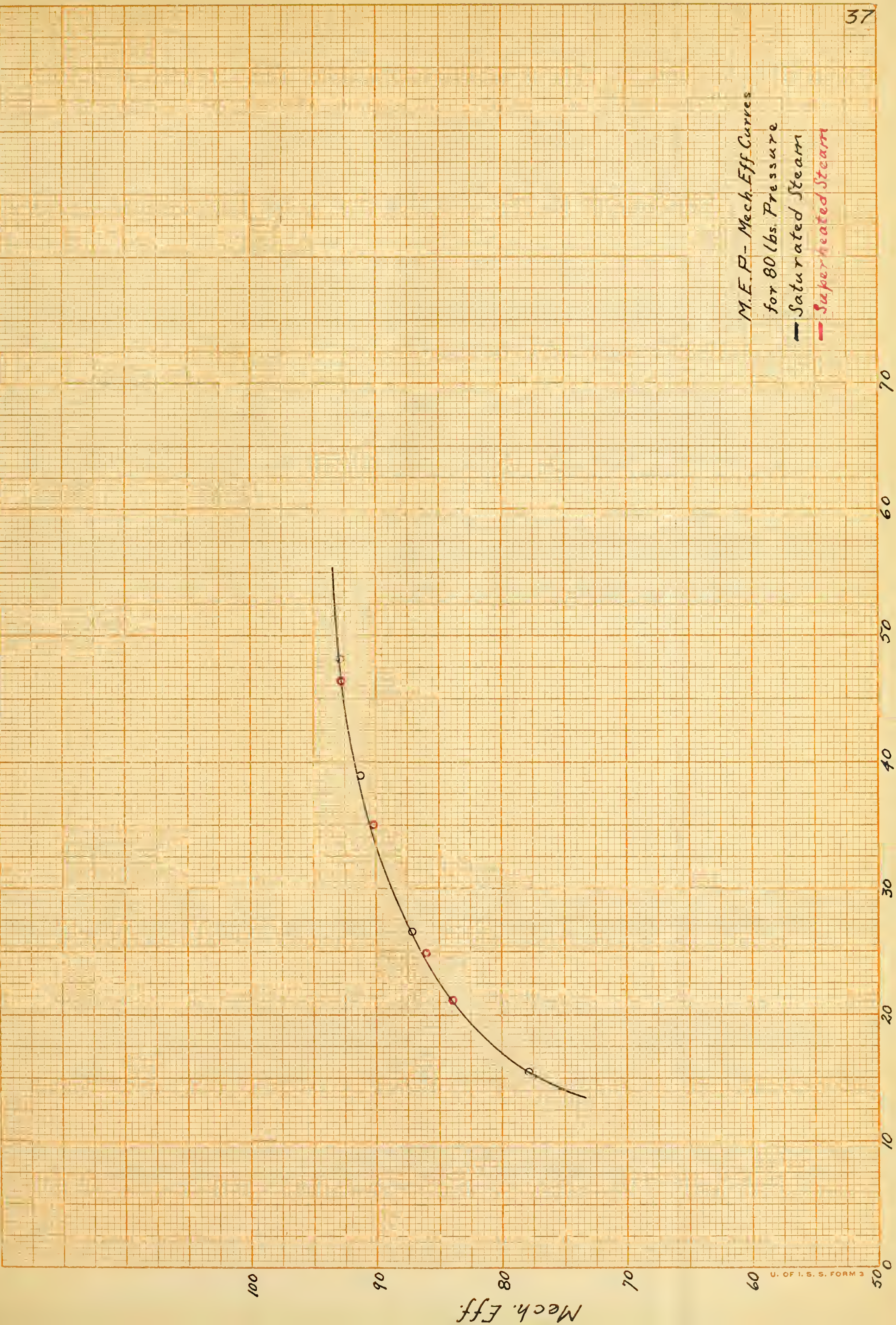

M.E.P.-Pot. Eff. Curve
for 100 lbs. Pressure
—Saturated Steam
—Superheated Steam
M.E.P.
0
10
20
30
40
50
60
70
80
Potential Eff.
10
20
30
40
50
60
U. OF I. S. S. FORM 3


M.E.P.-Pot. Eff. Curve
for 120 lbs. Pressure
—Saturated Steam
—Superheated Steam
M.E.P.
0
10
20
30
40
50
60
70
80
Potential Eff.
0
10
20
30
40
50
60
U. OF I. S. S. FORM 3


M.E.P. - Potential Eff. Curve
for 140 lbs. Pressure
—Saturated Steam
—Superheated Steam

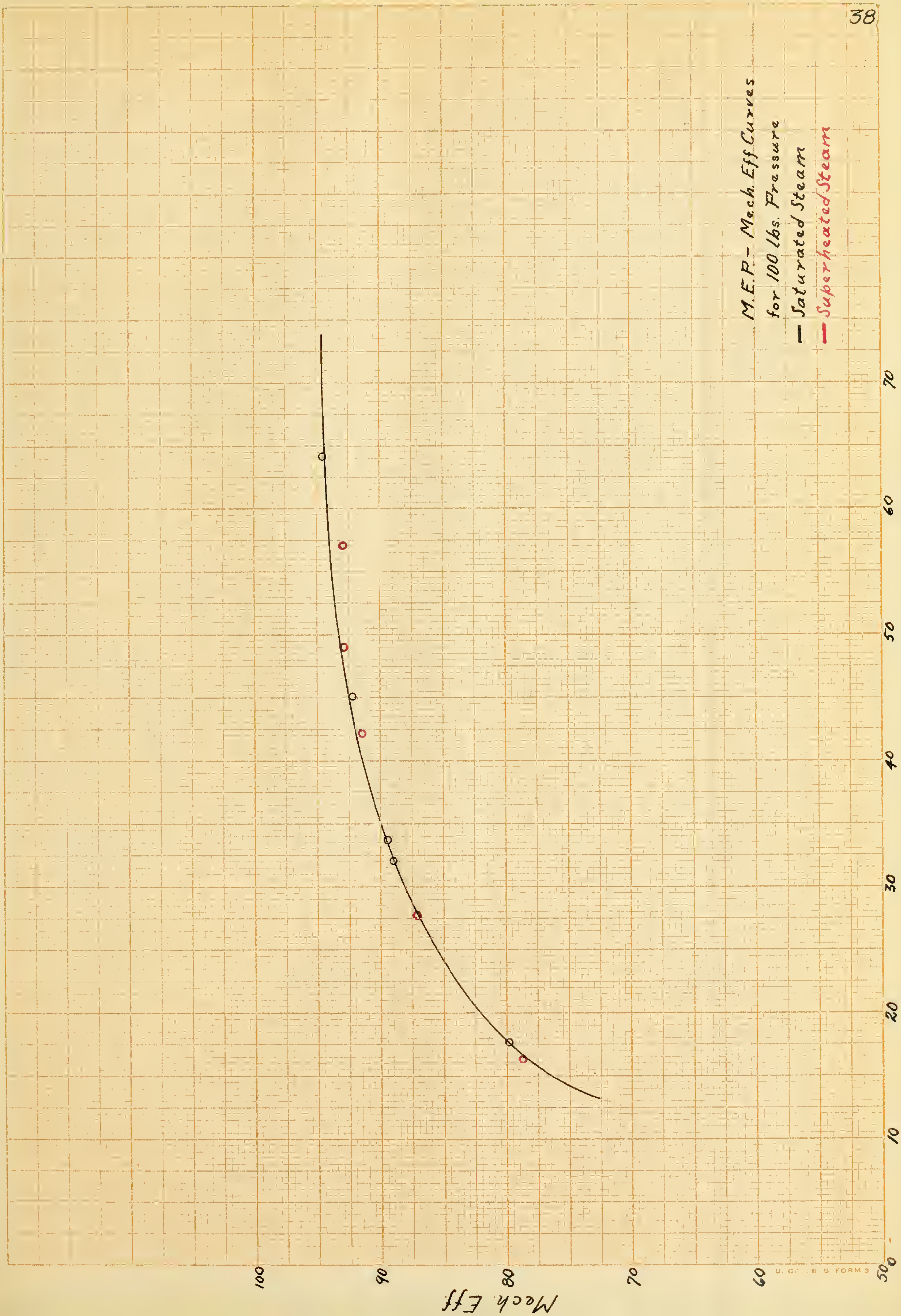
U. OF I. S. S. FORM 3

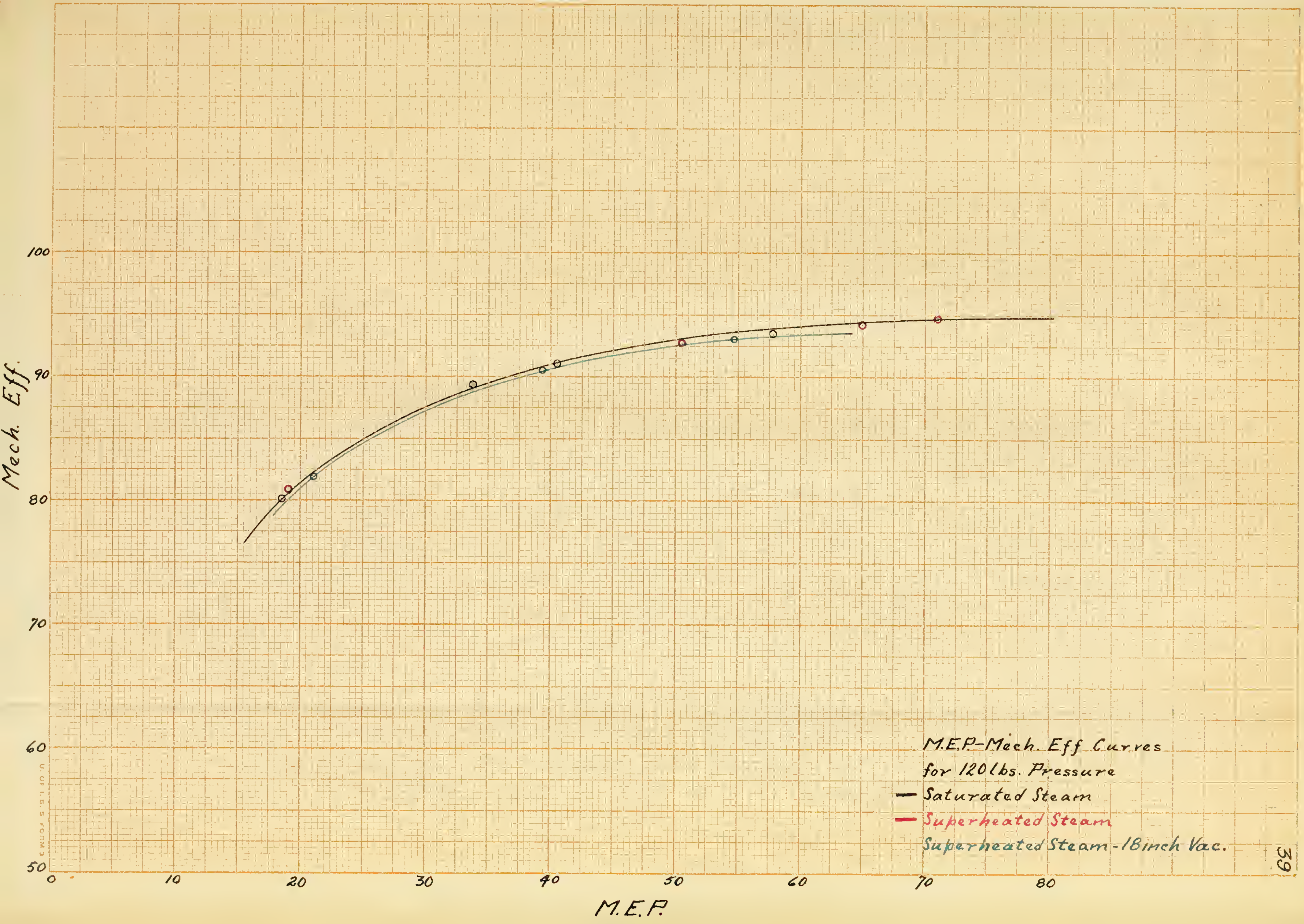

M.E.P.- Mech. Eff. Curves
for 60 lbs. Pressure
Saturated Steam
Superheated Steam
Mech. Eff.
100
90
80
70
60
50
M.E.P.
0
10
20
30
40
50
60
70

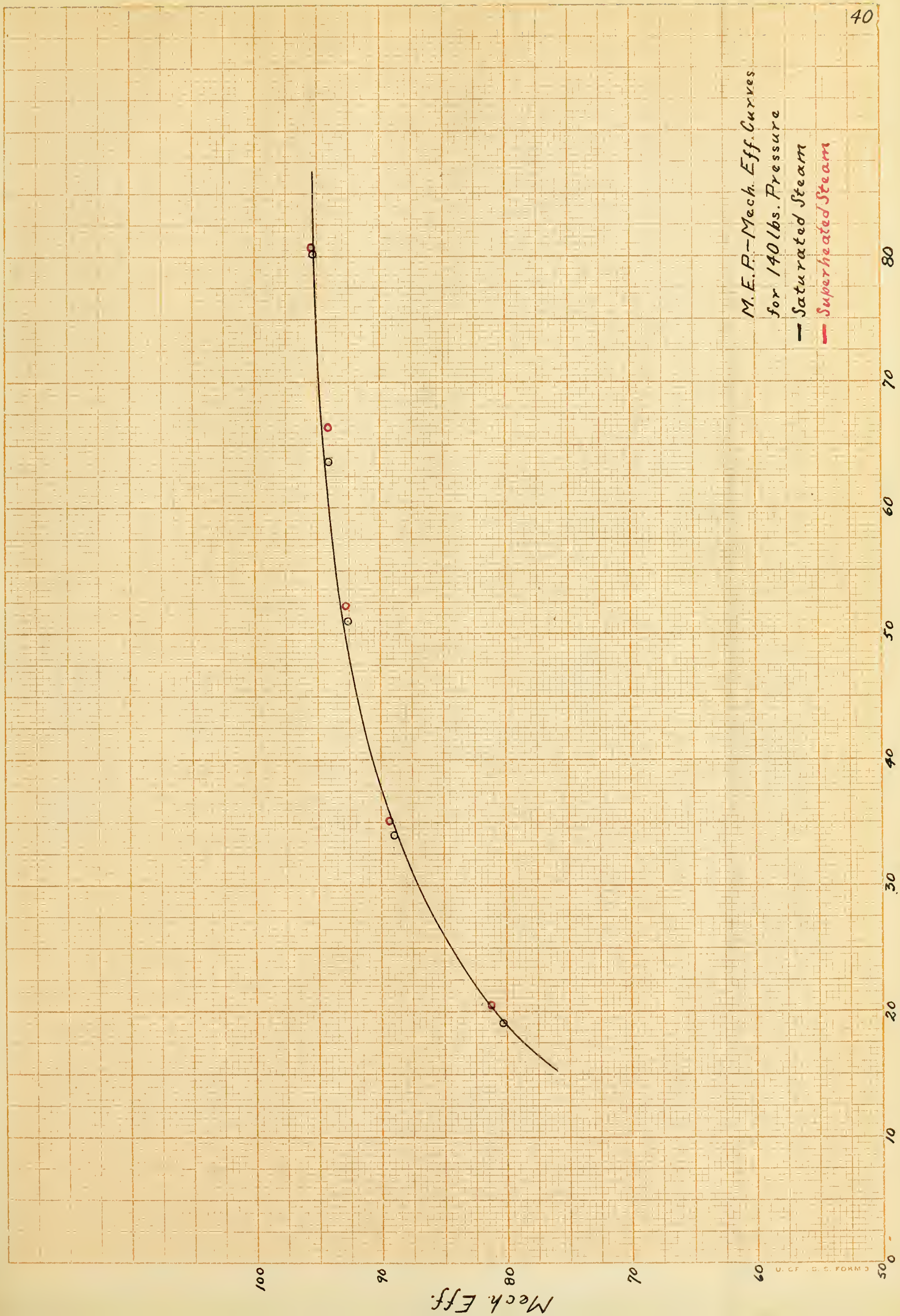


M.E.P.- Mech. Eff. Curves
for 80 lbs. Pressure

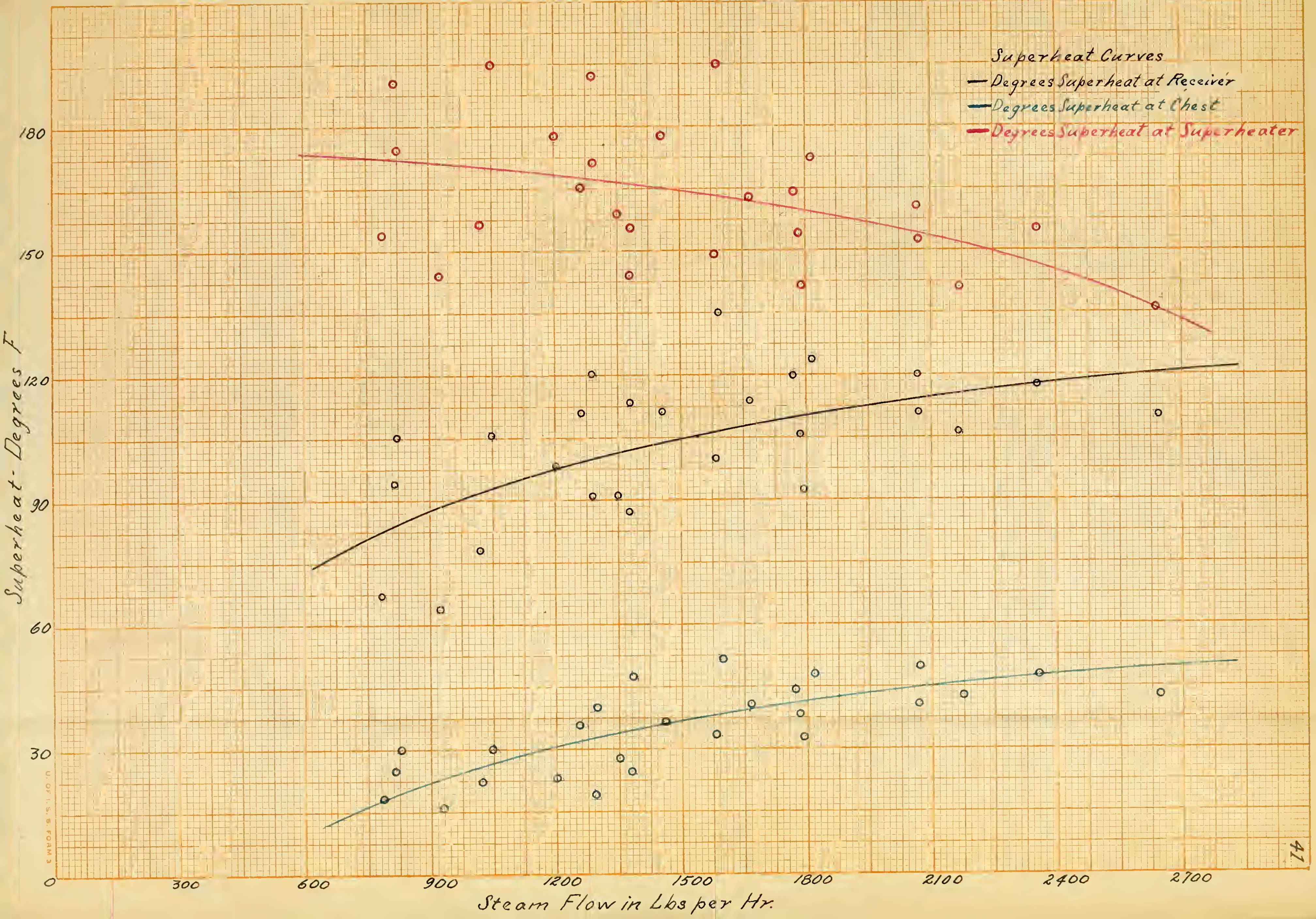
— Saturated Steam
— Superheated Steam


M.E.P.- Mech. Eff. Curves
for 100 lbs. Pressure
— Saturated Steam
— Superheated Steam
M.E.P.
0
10
20
30
40
50
60
70
Mech Eff
50
60
70
80
90
100

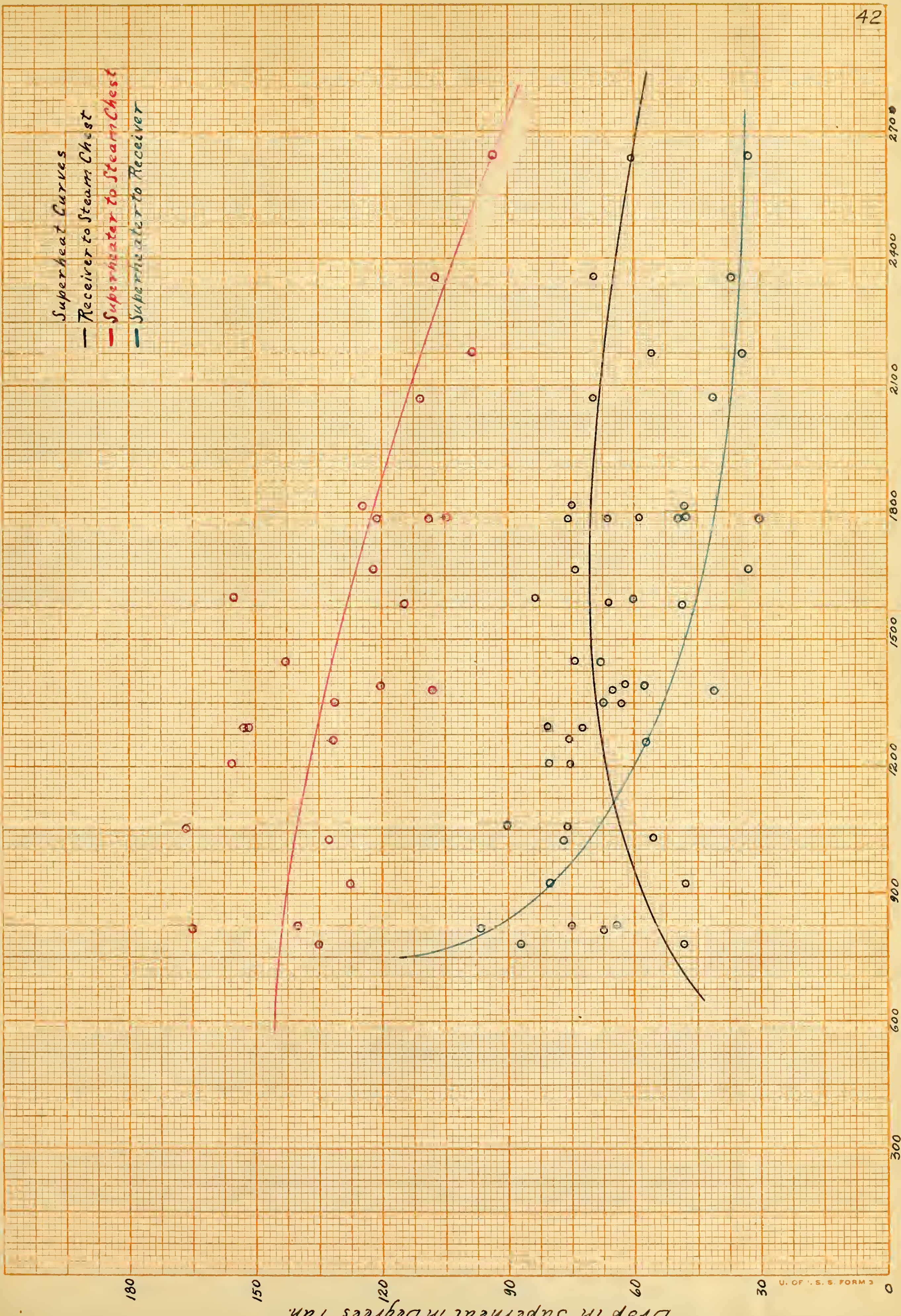

M.E.P.-Mech. Eff Curves
for 120 lbs. Pressure
— Saturated Steam
— Superheated Steam
Superheated Steam - 18 inch Vac.
Mech. Eff.
100
90
80
70
60
50
M.E.P.
0
10
20
30
40
50
60
70
80
U. OF I. S. S FORM 3

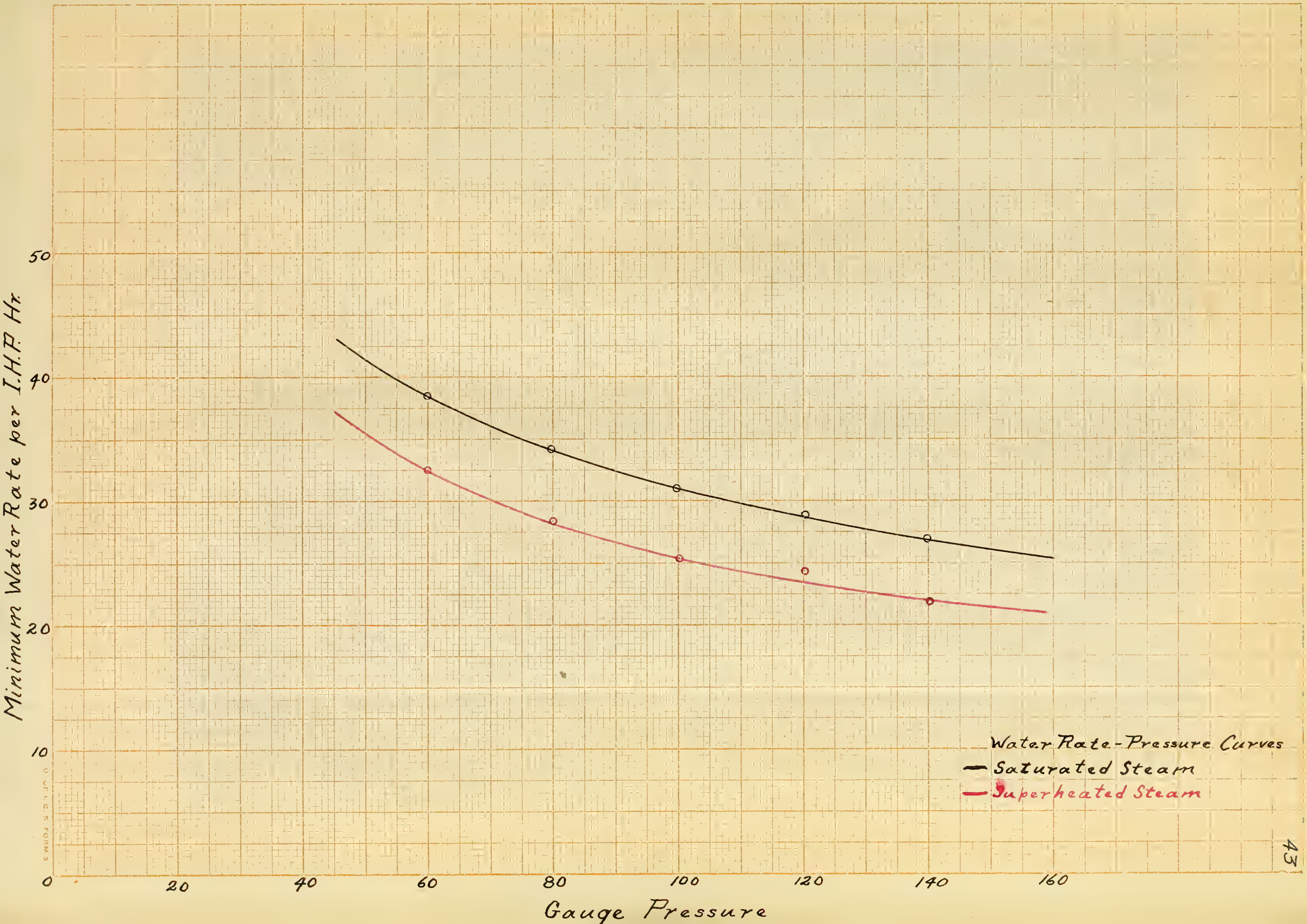


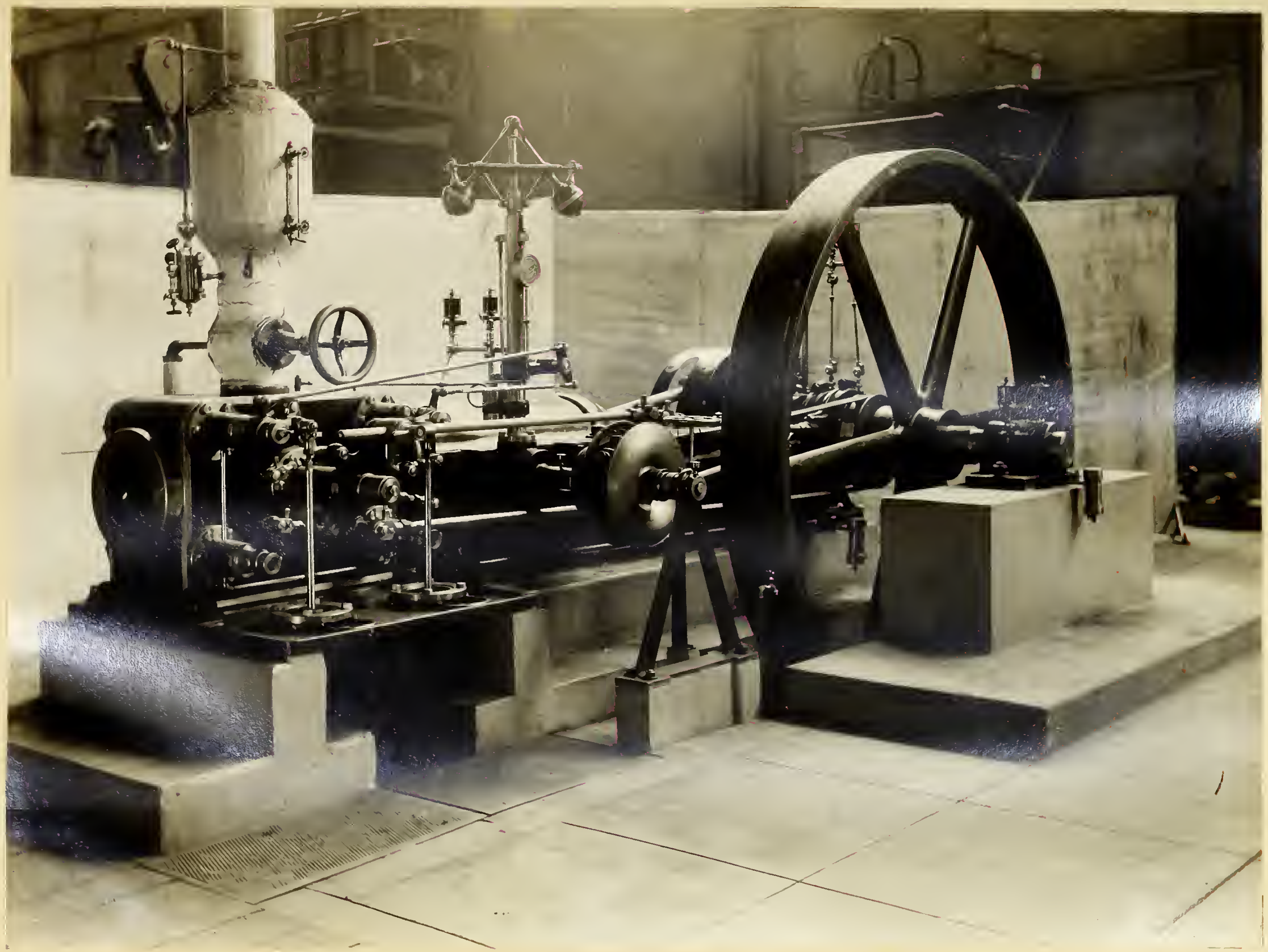
M.E.P.-Mech. Eff. Curves
for 140 lbs. Pressure

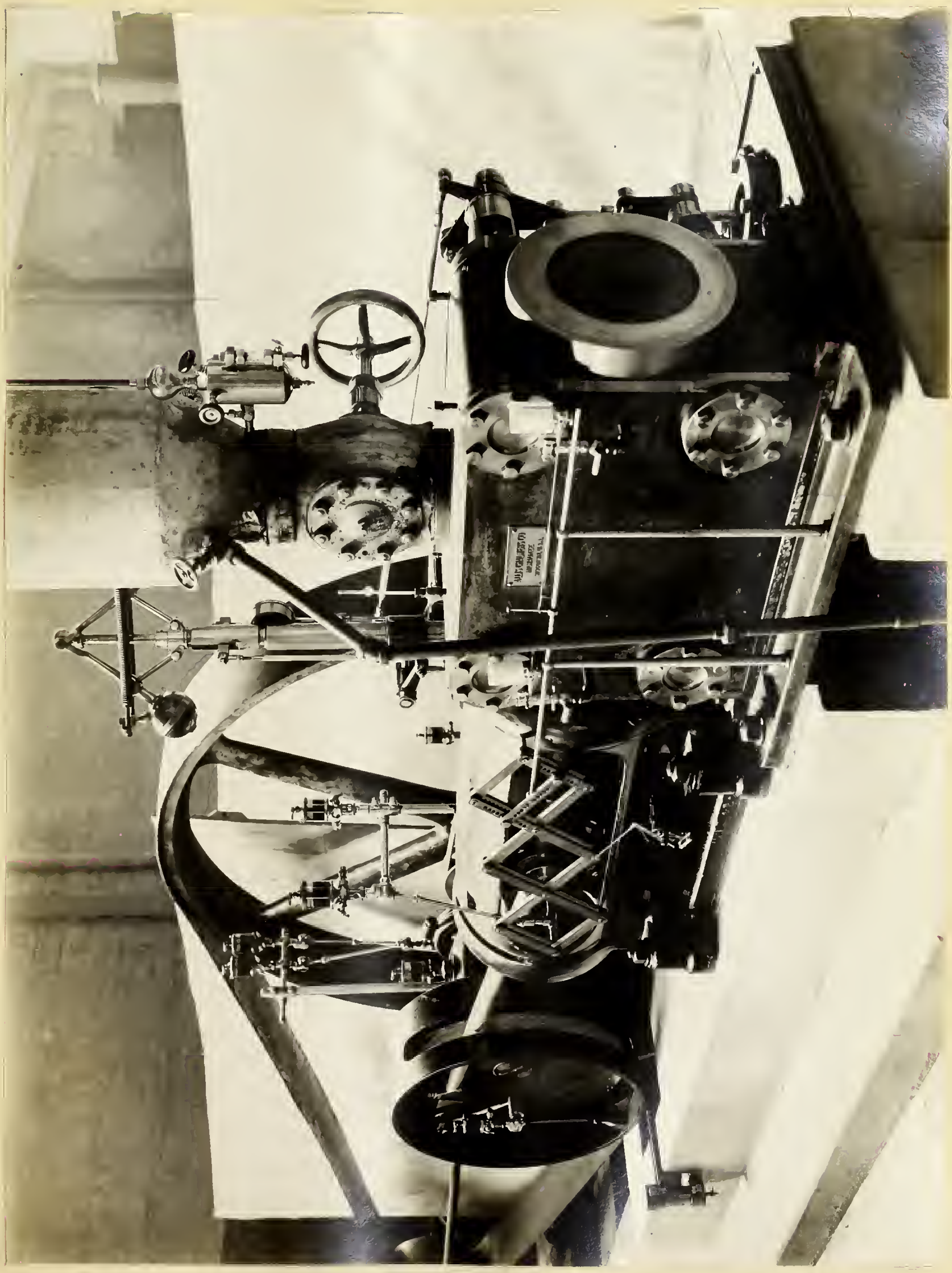


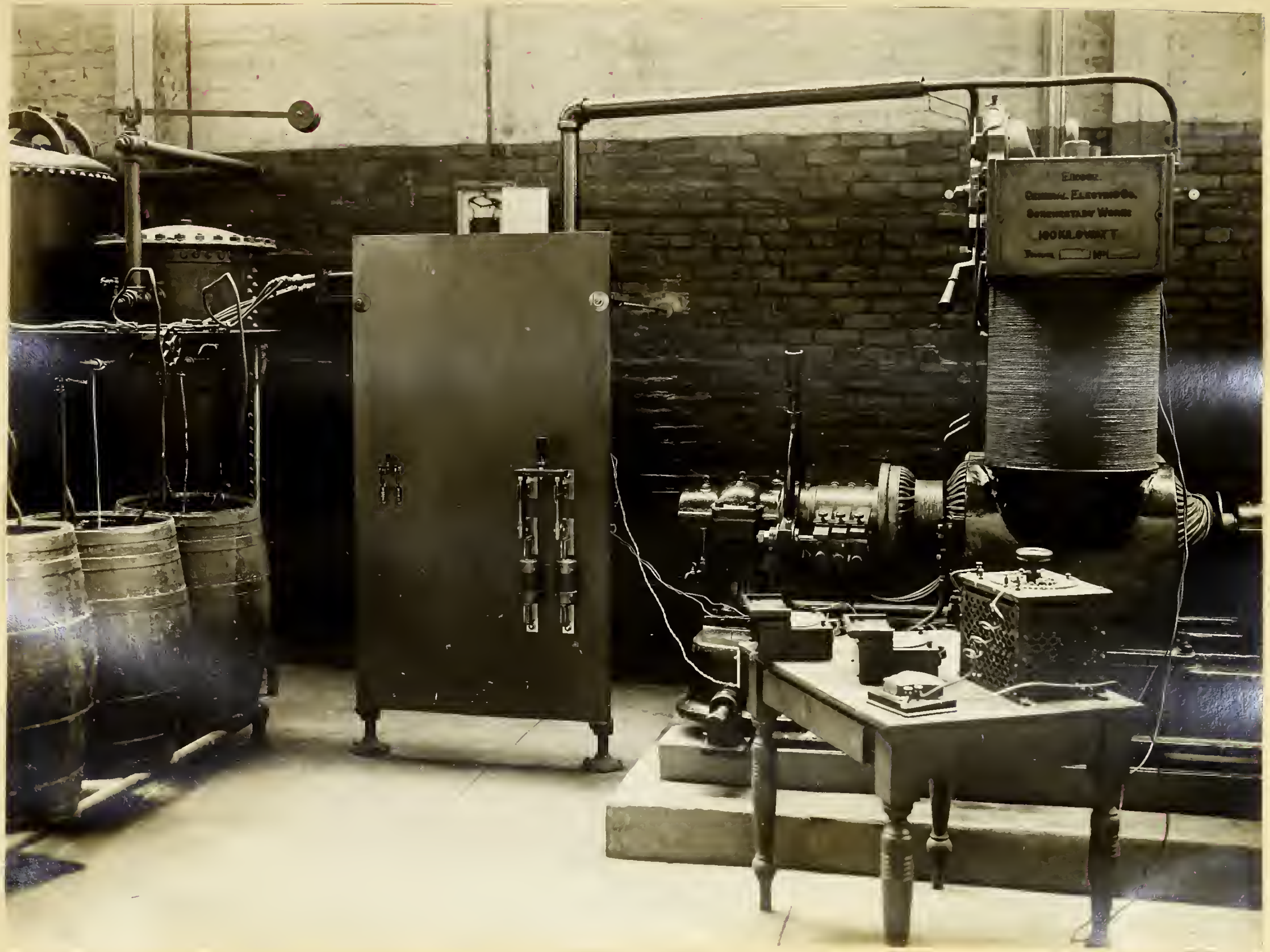
U. OF I. S. S. FORM 3

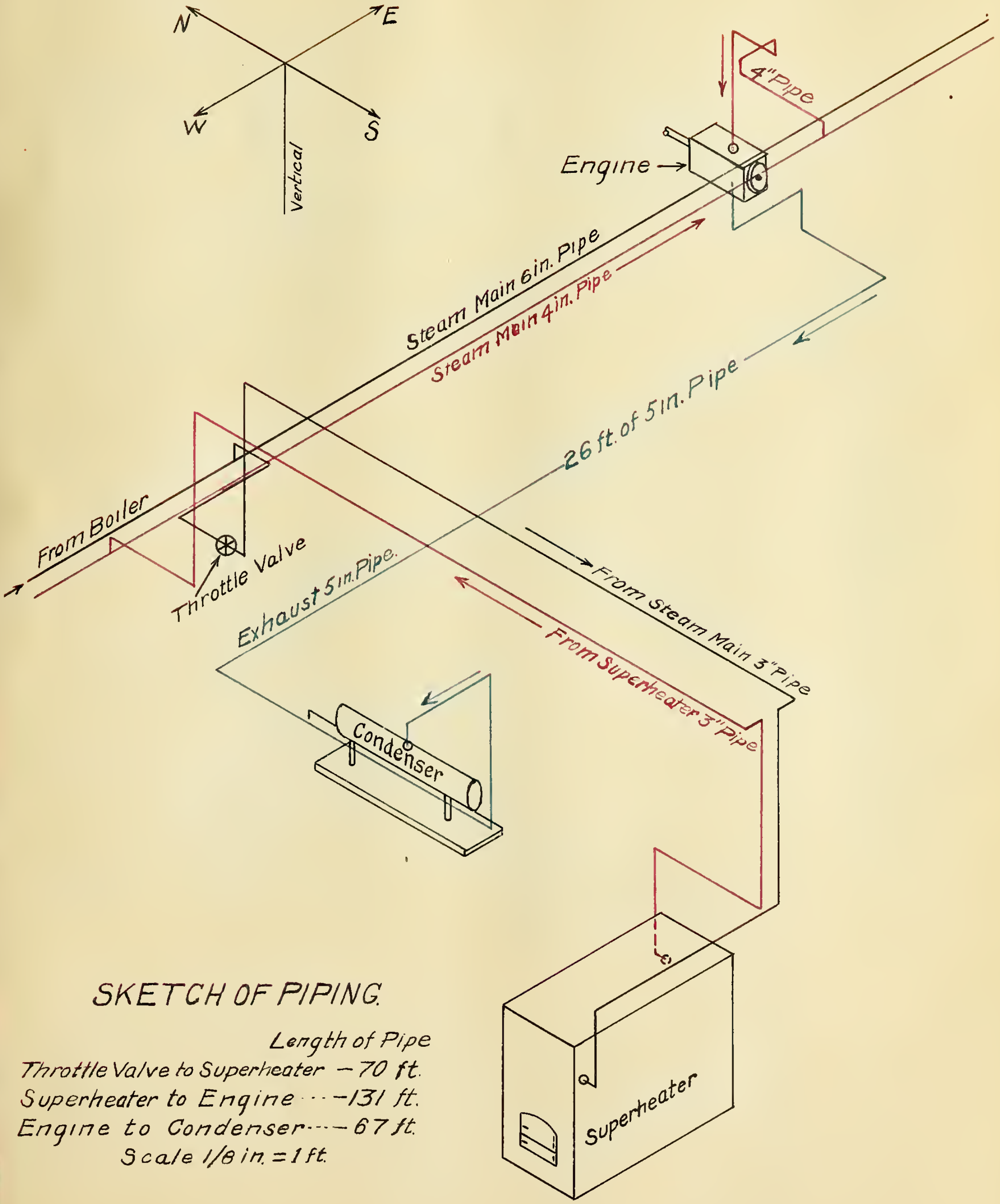

Superheat Curves
— Receiver to Steam Chest
— Superheater to Steam Chest
— Superheater to Receiver
Steam Flow in Lbs per Hr.
Drop in Superheat in Degrees Fah.
0
300
600
900
1200
1500
1800
2100
2400
2700
180
150
120
90
60
30
0
U. OF I. S. S. FORM 3


Water Rate-Pressure Curves
Saturated Steam
Superheated Steam
Minimum Water Rate per I.H.P. Hr.
Gauge Pressure
0
10
20
30
40
50
20
40
60
80
100
120
140
160






General Electric Co.
Schenectady Works
100 Kilowatt



SKETCH OF PIPING.

Length of Pipe
Throttle Valve to Superheater – 70 ft.
Superheater to Engine ···–131 ft.
Engine to Condenser···– 67 ft.
Scale 1/8 in. = 1 ft.

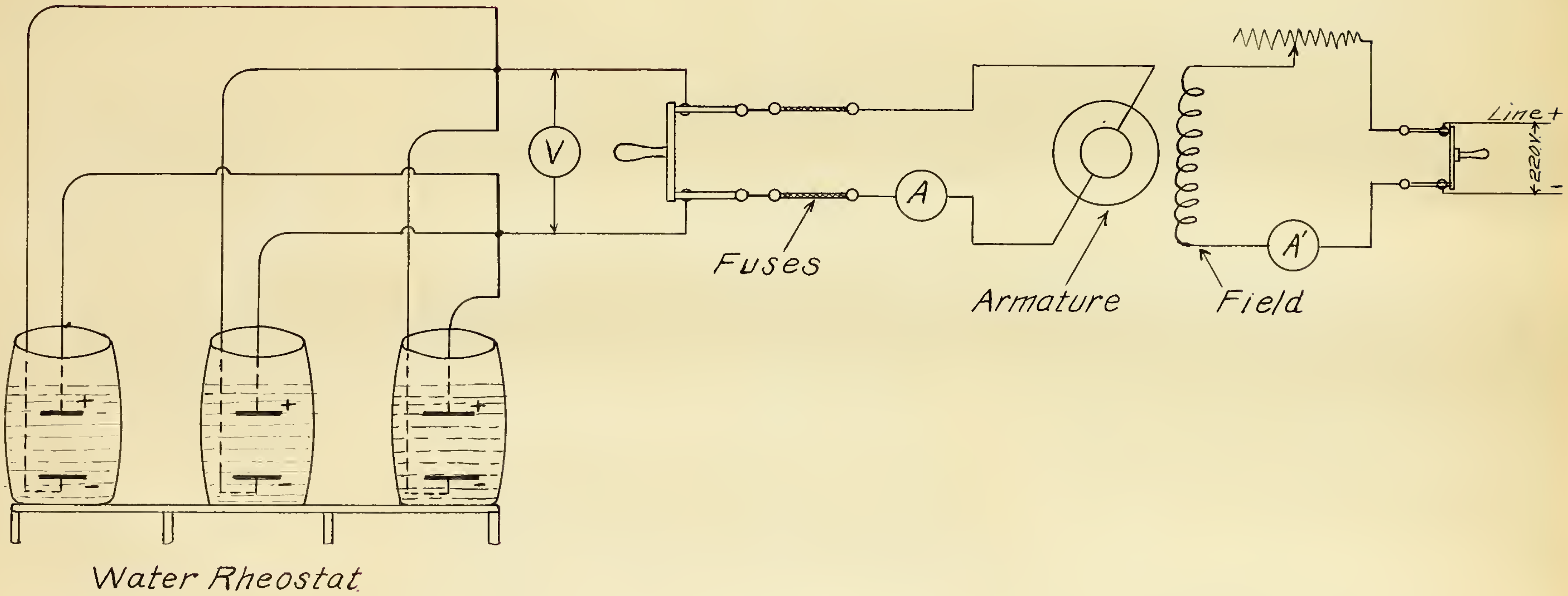


DIAGRAM OF CONNECTIONS.

H.E.

C.E.

M.E.P.---C.E.= 35.2 lbs.

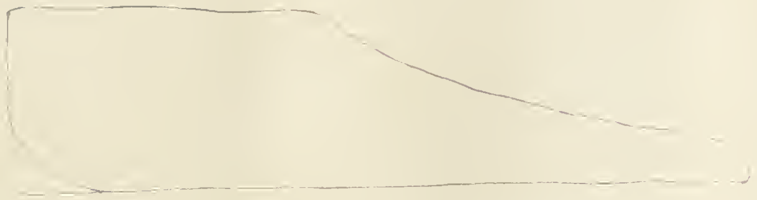
M.E.P.---H.E.= 30.8 lbs.

R.P.M.--------= 120

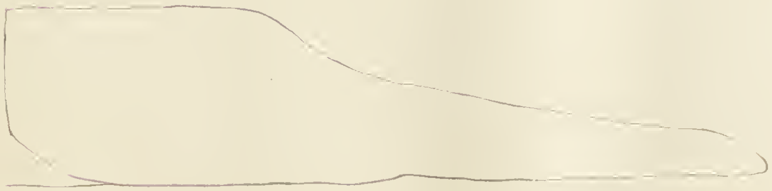
Pressure------= 60 lbs.

Superheat----= 135 degrees F.

C.E.



H. E.



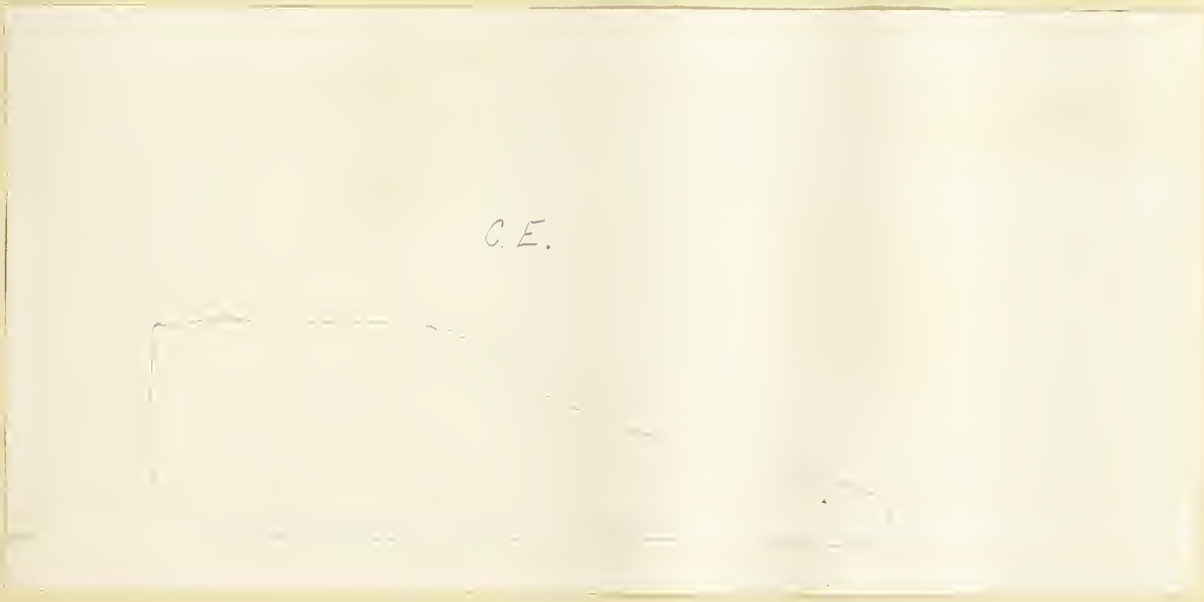
M.E.P.---C.E.= 48.75 lbs.

M.E.P.---H.E.= 44.1 lbs.

R.P.M.-------= 120

Pressure-----= 80 lbs.

Superheat----= 123.5 degrees F.



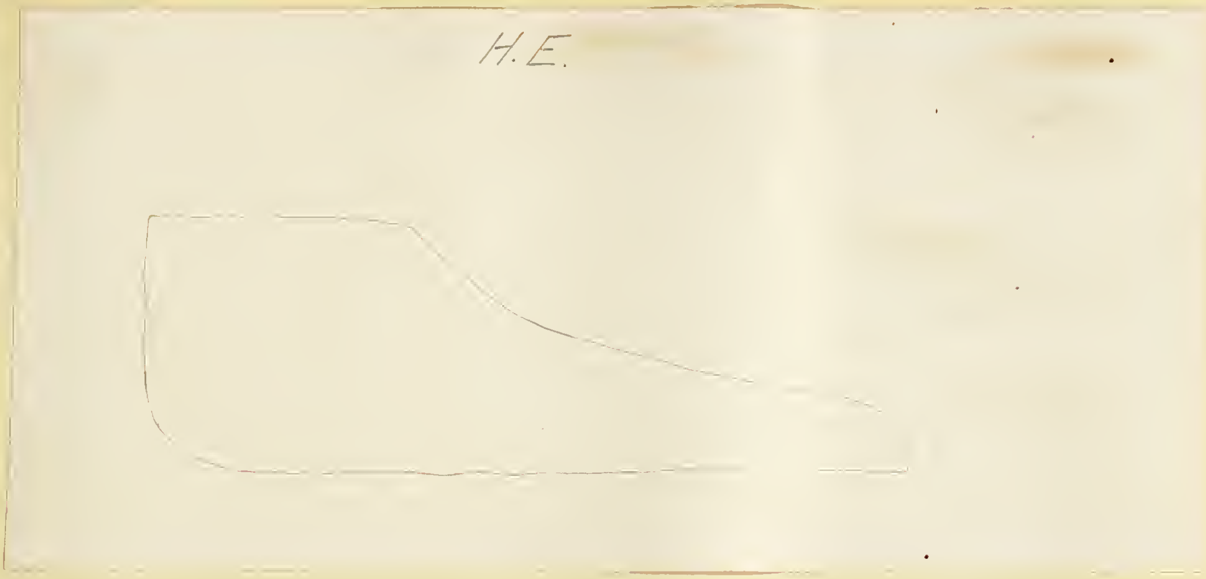
M.E.P.---C.E.= 59.3 lbs.

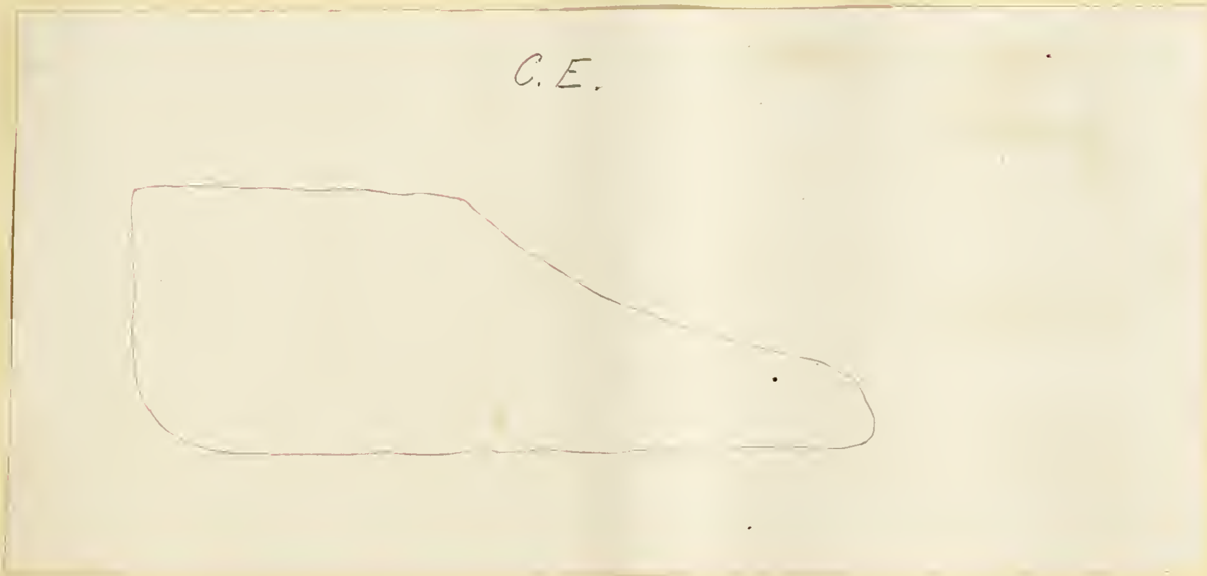
M.E.P.---H.E.= 52.1 lbs.

R.P.M.--------= 120

Pressure-----= 100 lbs.

Superheat----= 119.6 degrees F,





M.E.P.---C.E.= 75.6 lbs.

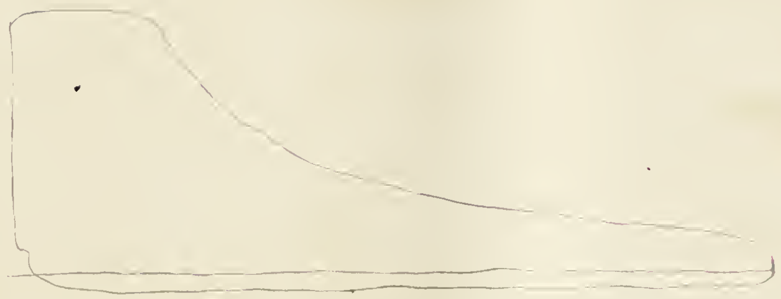
M.E.P.---H.E.= 67.3 lbs.

R.P.M.--------= 120

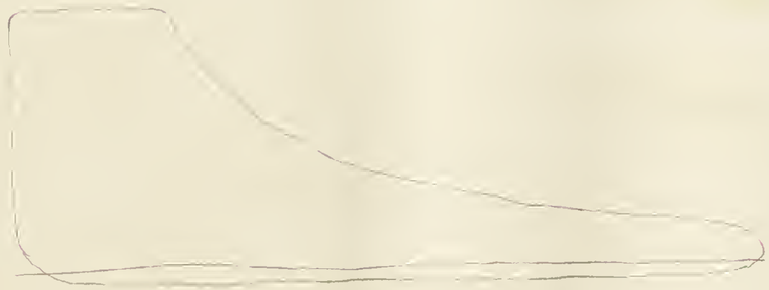
Pressure-----= 120 lbs.

Superheat----= 117.7 degrees F.

H.E.



C.E.



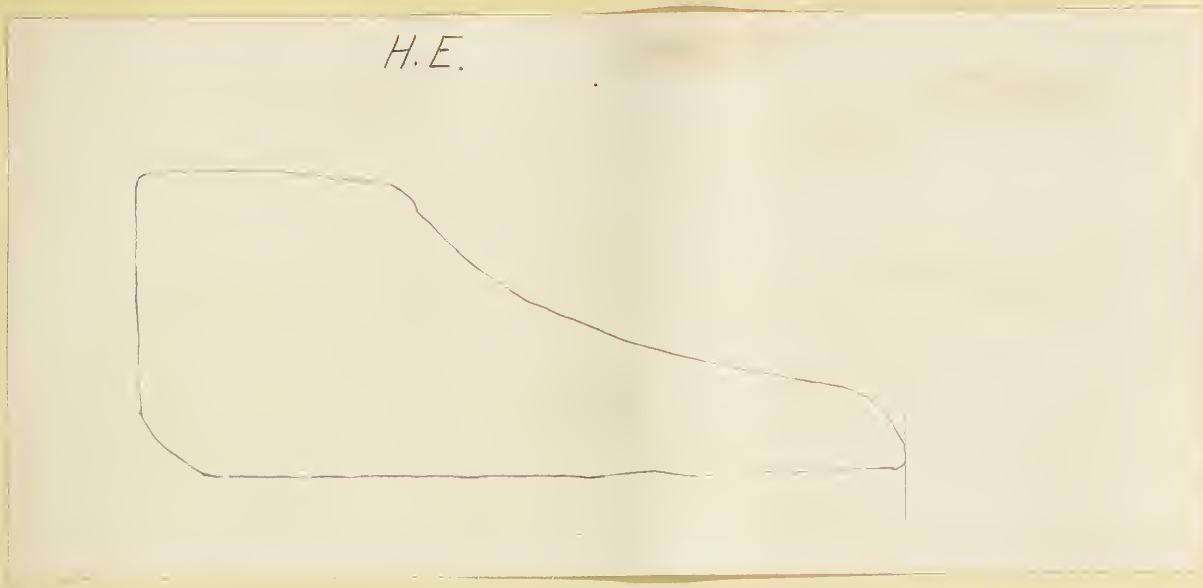
M.E.P.---C.E.= 54.8 lbs.

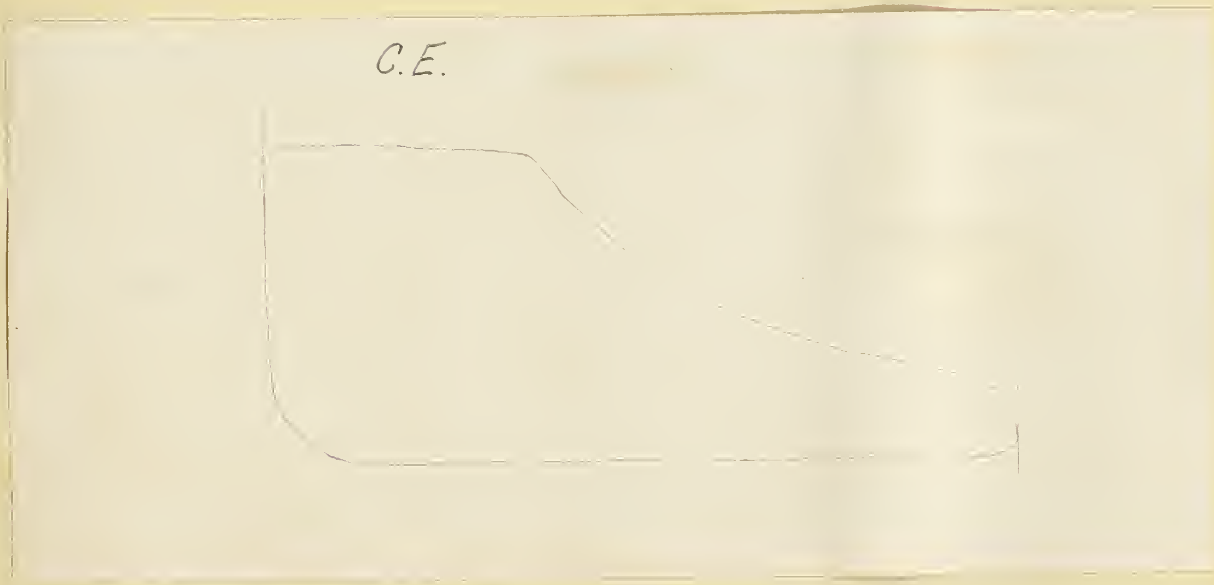
M.E.P.---H.E.= 55.6 lbs.

R.P.M.--------= 120

Pressure-----= 120 lbs.--20 in. Vacuum.

Superheat----= 105.8 degrees F,





M.E.P.---C.E.=81.6 lbs.

M.E.P.---H.E.= 79.25 lbs.

R.P.M.-------= 120

Pressure-----= 140lb,

Superheat----= 102.7 degrees,F.

GENERAL LOG OF TESTS ON 100 H.P. CORLISS ENGINE USING SUPERHEATED STEAM. SHEET 1

— TESTS — 500° Series – 120 R.P.M.	TEMPERATURES — FAHRENHEIT.								GAGE PRESS #/□"		IN. OF MERCURY		ABS. PRESS. #/□"		LOAD				
	Steam at Superht'r	Steam Pipe (Receiver)	Calorimeter	Steam Chest	Condensing In	Water Out	Condensate	Engine Room	Steam Main	Calorimeter (Receiver)	Barometer Press.	Vacuum	Steam Main	Calorimeter (Receiver)	Amperes	Volts	K.W.	Field Amperes	R.P.M.
60#/□" – 8 K.W.	498.8	400.8	326.4	332.5	60.3	64.1	73.6	72.0	60.3	59.5	29.41		74.74	73.94	55.8	144.3	8.06	8.83	117.3
60 16	503.5	413.8	333.4	337.8	57.1	62.6	73.6	73.0	60.5	60.5	29.41		74.94	74.94	114.7	140.1	16.06	8.93	114.2
60 24	499.4	424.5	345.4	344.5	56.0	63.5	73.9	74.0	59.4	57.7	29.41		73.84	72.14	179.1	134.1	24.01	9.38	108.7
60 28	502.4	440.0	360.9	357.0	56.0	65.0	76.0	74.0	60.0	57.8	29.41		74.44	72.24	218.1	130.0	28.37	9.72	104.4
80 10	500.4	418.4	326.1	343.7	46.9	53.6	68.4	69.5	78.8	76.1	29.57		93.32	90.62	75.4	138.1	10.42	9.30	110.9
80 21	494.5	413.0	311.2	340.6	48.2	54.9	70.1	68.8	79.3	77.4	29.57		93.82	91.92	151.2	137.2	20.75	9.85	109.2
80 31	502.0	432.0	353.0	358.0	47.7	56.1	71.3	71.8	79.1	76.3	29.57		93.62	90.82	230.3	132.4	30.50	10.20	105.3
80 40	495.3	444.2	371.2	369.1	48.4	61.8	78.9	71.3	79.1	76.0	29.57		93.62	90.52	334.0	120.1	40.10	9.87	98.5
100 13	504.3	439.0	378.6	363.8	55.2	88.5	73.0	65.4	94.6	94.3	29.41		109.04	108.74	89.7	145.2	13.02	8.86	118.5
100 26	499.8	441.0	377.3	366.2	57.5	96.4	78.4	71.0	95.0	93.0	29.41		109.04	107.44	186.5	139.4	26.00	9.10	115.6
100 39	499.5	449.2	387.0	375.5	54.4	82.5	81.8	72.0	98.6	95.5	29.41		113.04	109.94	297.8	129.9	38.70	9.30	111.4
100 45	501.4	454.0	378.0	378.2	54.2	68.0	87.9	65.9	98.9	94.7	29.207		113.25	109.05	372.1	121.1	45.08	8.30	108.3
100 52	498.0	454.0	382.0	383.9	46.0	70.7	74.8	66.0	99.4	95.1	29.207		113.75	109.45	420.4	122.5	51.50	9.70	104.0
120 16	502.0	425.4	364.9	369.6	61.9	71.5	78.5	65.7	114.0	115.2	29.207		128.35	129.55	115.6	140.2	16.21	8.17	118.3
120 32	501.0	439.4	375.2	374.6	47.8	63.9	73.3	65.4	112.6	114.3	29.207		126.95	128.65	229.3	139.8	32.06	8.24	115.5
120 48	494.3	446.5	382.5	380.9	44.0	65.1	74.4	65.8	112.9	114.1	29.207		127.25	128.45	370.9	129.0	47.85	9.30	111.0
120 60	500.1	457.5	381.9	387.1	52.8	77.8	85.4	75.6	117.1	114.1	29.09		131.38	128.38	499.6	119.6	59.75	9.48	105.4
120 62	502.5	463.2	392.1	393.1	48.3	63.6	81.5	71.5	115.4	112.3	29.57		129.92	126.82	528.2	117.2	61.91	10.20	99.0
120 17 20" V	500.6	413.0	343.0	365.5	56.5	62.5	86.7	72.8	114.2	113.7	29.137	18.0	128.52	128.02	121.8	139.1	16.95	8.20	119.5
120 35 20" V	504.7	436.3	363.2	373.3	54.0	67.4	79.4	70.3	113.0	113.0	29.137	18.3	127.32	127.32	250.0	140.0	35.00	9.22	117.1
120 51 20" V	499.5	451.6	383.7	385.0	53.8	73.4	82.3	68.4	113.1	113.0	29.137	17.8	127.42	127.32	377.0	134.8	50.81	9.80	113.2
140 17	500.0	420.6	353.4	372.5	52.5	61.4	71.0	72.4	131.8	132.5	29.09		146.08	146.78	116.0	145.9	16.93	9.10	118.9
140 34	499.7	441.0	371.0	379.0	57.1	71.7	78.0	71.0	130.0	128.0	29.09		144.28	142.28	245.2	140.0	34.33	9.10	116.8
140 51	499.3	448.3	384.0	389.2	53.0	72.0	79.9	73.7	133.9	131.3	29.09		148.28	145.58	379.5	134.1	50.88	9.30	113.5
140 63	499.2	462.2	392.3	398.7	53.9	73.5	83.5	70.8	135.7	131.0	29.15		150.02	145.32	502.0	126.2	63.35	9.43	110.3
140 73	495.0	459.7	389.3	399.0	49.5	67.0	84.0	74.8	137.5	132.6	29.57		152.02	147.12	623.7	116.7	72.79	10.12	101.5

GENERAL LOG OF TESTS ON 100 HP. CORLISS ENGINE USING SUPERHEATED STEAM.

SHEET 2.

—TESTS— 500° Series—120 R.P.M.	SUPERHEAT — °FAHRENHEIT					AVERAGE M.E.P.			I.H.P.			B.H.P.		WATER RATE.		EFFICIENCIES	
	At Superheater.	At Receiver.	Drop from Superheater to Receiver.	At Steam Chest.	Drop from Receiver to Chest.	H.E.	C.E.	No Load.	H.E.	C.E.	Total.	Total.	Condensate per hour. lb.	Per I.H.P. hour.	Per B.H.P. hour.	Mechanical.	Potential.
60 c — 8 K.W.	191.4	94.2	97.2	25.9	68.3	12.72	13.62	3.21	10.28	10.63	20.91	14.45	815	38.95	56.4	69.1	51.0
60 16	196.0	106.3	89.7	30.3	76.0	19.33	20.47		15.20	15.54	30.74	25.78	1058	34.40	41.0	83.9	55.7
60 24	192.8	119.6	73.2	39.6	80.0	26.55	28.51		19.85	20.62	40.47	35.75	1288	31.85	36.0	88.4	61.9
60 28	195.3	135.0	60.3	52.0	83.0	30.45	34.80		21.88	24.20	46.08	41.50	15.96	34.65	38.4	90.2	56.5
80 10	177.5	97.6	79.9	22.9	74.7	21.23	21.98	3.44	16.21	16.23	32.44	27.24	1202	37.07	44.2	84.0	48.0
80 21	171.2	91.3	79.9	18.9	72.4	24.70	25.38		18.57	18.40	36.97	31.85	1294	35.04	40.7	86.2	47.2
80 31	178.9	111.1	67.8	37.1	74.0	34.10	36.15		24.72	25.33	50.05	45.10	1455	29.09	32.3	90.1	60.4
80 40	172.2	123.5	48.7	48.4	75.1	43.87	48.90		29.70	32.00	61.70	57.20	1822	29.55	31.9	92.7	57.0
100 13	170.2	105.1	65.1	29.9	75.2	15.70	17.32	3.58	12.80	13.64	26.44	20.72	822	31.09	39.7	78.4	51.2
100 26	165.4	108.0	57.4	33.2	74.8	27.60	27.89		21.95	21.42	43.37	37.80	1260	29.09	33.4	87.2	55.0
100 39	162.7	114.4	48.3	40.7	73.7	41.48	42.88		31.80	31.80	63.60	58.15	1660	26.10	28.6	91.4	60.5
100 45	164.4	119.9	44.5	44.1	75.8	48.20	49.80		35.95	35.90	71.85	66.60	1780	24.78	26.7	92.7	64.3
100 52	160.7	119.6	41.1	49.5	70.1	54.15	60.40		38.75	41.79	80.54	72.60	2072	25.72	28.5	90.2	57.5
120 16	155.6	78.3	77.3	22.5	55.8	16.90	21.40	3.69	13.74	16.84	30.58	24.74	914	29.90	36.9	81.0	50.6
120 32	155.4	112.8	42.6	48.0	64.8	32.10	34.95		25.51	26.84	52.35	46.66	1380	26.36	28.4	89.2	55.8
120 48	148.5	100.0	48.5	34.4	65.6	49.25	51.65		37.65	38.13	75.78	70.25	1906	25.15	27.1	92.7	59.1
120 60	151.9	111.7	40.8	40.7	70.4	63.45	66.90		46.09	46.90	92.99	87.65	2315	24.93	26.4	94.3	59.0
120 62	155.1	117.7	37.4	47.6	70.1	66.50	75.55		45.30	49.70	95.00	90.15	2350	24.75	26.1	94.9	59.8
120 17 20″V.	154.1	66.8	87.3	19.3	47.5	18.27	23.59	3.69	15.20	18.71	33.91	27.83	786	23.15	28.2	82.0	49.8
120 35 20″V	158.9	90.5	68.4	27.5	63.0	38.25	40.40		30.81	31.47	62.28	56.43	1352	21.73	24.0	90.6	50.2
120 51 20″V	153.6	105.8	47.8	39.2	66.6	54.60	54.95		42.60	41.41	84.01	78.15	1786	21.25	22.8	93.0	51.3
140 17	143.7	63.8	79.9	15.7	48.1	19.05	21.65	3.77	15.60	17.12	32.72	26.67	922	28.16	34.6	81.5	50.8
140 34	144.3	86.7	57.6	24.7	62.0	35.00	35.38		28.14	27.49	55.63	49.64	1384	24.90	27.6	89.3	57.4
140 51	141.8	92.2	49.6	33.1	59.1	50.70	53.65		39.62	40.50	80.12	74.31	1789	22.33	24.1	92.8	63.8
140 63	141.0	106.2	34.8	42.7	63.5	65.55	67.60		49.80	49.60	99.40	93.75	2171	21.85	23.2	94.3	60.4
140 73	135.5	102.7	32.8	42.0	60.7	80.10	81.65		56.00	55.10	111.10	105.80	2640	23.79	24.9	95.3	59.2

GENERAL LOG OF TESTS ON 100 HP. CORLISS ENGINE USING SATURATED STEAM.

SHEET 1.

— TESTS — 120 R.P.M.		TEMPERATURES °FAHRENHEIT.					PRESSURES. #/□"						
		At Calorimeter	Condensing In	Water Out	Condensate.	Engine Room	At Calorimeter Gage	At Calorimeter. Absolute	Barometer	Superheat in Calorimeter	Quality of Steam	R. P. M.	Condensate per hour in lb.
60#/□" —	0 K.W	244.2	67.6	77.2	82.1	80.0	57.8	72.2	14.40	33.3	.986	119.0	578.
60	12	240.5	76.0	81.0	91.7	81.3	57.8	72.1	14.30	29.9	.984	107.1	1054.
60	16	228.1	66.0	90.8	82.8	67.9	57.3	71.5	14.17	17.0	.975	101.7	1105.
60	32	214.8	64.1	92.0	88.5	69.5	55.8	70.2	14.46	3.7	.968	105.0	2010.
80	0	257.8	69.3	71.7	78.1	79.9	77.0	91.4	14.40	46.9	.986	119.7	582.
80	13	257.7	80.6	87.5	94.0		77.0	91.3	14.30	47.1	.987	114.1	1010.
80	25	244.3	60.5	78.4	79.7	68.9	76.7	90.9	14.17	34.2	.979	107.3	1384.
80	38	216.0	64.0	79.8	87.0	69.5	75.6	90.0	1446	4.9	.964	110.7	2104
80	45	217.7	64.2	92.0	93.0	70.0	75.0	89.4	14.46	6.6	.966	104.7	2559
100	0	268.0	66.6	69.2	77.1	79.3	97.0	111.4	14.40	57.1	.988	120.1	560
100	15	272.0	77.0	86.0	91.0	81.2	95.8	110.1	14.30	61.4	.991	115.7	1048
100	34	261.5	65.4	76.5	84.0	67.5	96.0	110.2	14.17	51.4	.984	108.5	1530
100	33	260.5	57.1	89.5	79.5	65.2	94.9	109.1	14.17	50.4	.984	107.2	1584
100	47	231.0	58.7	80.2	84.5	66.5	94.5	108.8	14.36	20.2	.969	112.5	2298
100	57	239.3	59.0	81.4	87.6	67.0	93.6	107.9	14.36	28.5	.973	106.8	2758
100	60	242.3	80.1	134.5	141.4	78.1	94.0	108.4	14.40	31.4	.975	99.3	3008
120	0	277.7	64.9	66.9	77.0	78.8	116.8	131.2	14.40	66.8	.989	119.7	532.
120	16	282.3	78.0	83.4	90.9	81.1	114.6	128.9	14.30	71.7	.997	117.4	1030.
120	34	271.7	61.4	71.0	80.5	64.9	113.7	127.9	14.17	61.6	.987	111.5	1566.
120	40	271.7	56.5	73.0	78.5	64.8	113.6	127.8	14.17	61.6	.987	107.8	1738.
120	62	277.2	77.0	96.5	109.5	79.3	112.0	126.2	14.21	66.9	.990	112.3	2664
140	0	290.0	65.5	67.4	79.5	80.4	134.0	148.4	14.40	79.1	.992	121.2	512
140	16	288.4	77.4	80.5	90.0	69.5	131.9	146.2	14.30	77.8	.992	118.1	986
140	34	285.5	61.5	69.3	81.3	68.0	133.2	147.4	14.17	75.4	.992	114.4	1466
140	49	282.6	67.4	87.0	93.2	66.2	132.0	146.2	14.17	72.5	.991	105.1	2000
140	68	287.4	78.8	153.9	114.9		130.8	145.0	14.21	66.1	.988	114.0	2796
140	77	274.6	77.6	114.5	122.5	77.5	132.0	146.4	14.41	63.6	.986	102.3	3276

GENERAL LOG OF TESTS ON 100 HP CORLISS ENG[illegible]USING SATURATED STEAM. SHEET 2.

— TESTS — 120 R.P.M		AVE. M.E.P. H.E.	AVE. M.E.P. C.E.	Total I.H.P.	Total B.H.P.	WATER RATE Per I.H.P.	WATER RATE Per B.H.P.	LOAD Volts.	LOAD Amperes.	LOAD K.W.	Field Amperes	EF[illegible]IES. Mechanic[illegible]	EF[illegible]IES. Potential.
60"/□" —	0 K.W.	3.54	3.67	5.17		110.1							19.5
60	12	16.45	15.43	23.08	18.43	44.9	56.2	84.2	150.0	12.63		79.9	47.2
60	16	1912	18.64	25.28	21.53	42.7	50.1	99.6	158.3	15.76	8.2	85.3	48.1
60	32	34.05	34.92	48.98	44.43	38.8	42.8	103.0	310.0	31.91		90.7	51.7
80	0	3.25	3.58	5.57		103.0							17.6
80	13	16.03	15.04	23.97	18.66	41.6	53.4	84.5	150.7	12.74		77.9	44.4
80	25	26.85	26.27	38.56	33.55	35.2	40.4	105.6	236.5	24.99	8.15	87.1	53.7
80	38	39.13	39.07	58.51	53.35	34.6	37.9	106.0	360.0	38.18		91.2	54.1
80	45	47.38	49.11	68.35	63.45	36.1	38.9	98.0	460.0	45.17		92.9	52.7
100	0	3.05	4.15	5.81		93.3							18.2
100	15	18.37	17.19	27.85	22.23	37.3	46.7	100.1	150.0	15.02		79.9	45.7
100	34	32.08	31.66	46.78	41.50	32.2	36.3	115.3	295.0	34.01	8.4	88.8	52.9
100	33	33.83	33.67	48.92	43.72	31.9	35.7	101.1	325.8	32.93	8.2	89.4	53.9
100	47	45.00	45.11	68.60	63.15	32.5	35.3	103.0	460.0	47.40		92.1	53.2
100	57	56.70	57.60	82.60	77.42	32.5	34.7	95.0	600.0	57.00		93.8	53.3
100	60	64.02	64.52	86.30	81.50	33.9	35.9	80.0	750.0	60.00		94.5	50.7
120	0	2.55	4.90	5.98		87.9							18.0
120	16	18.56	18.37	29.33	23.48	34.9	43.6	104.7	150.0	15.70		80.1	44.2
120	34	34.39	33.50	51.11	45.62	29.2	32.7	109.8	308.5	33.89	8.9	89.3	52.9
120	40	40.78	40.29	58.72	53.38	29.4	32.3	103.3	398.0	39.93	8.3	90.9	54.7
120	62	57.48	58.33	84.10	78.70	31.4	33.6	100.0	620.0	62.00		93.6	51.1
140	0	1.70	5.86	6.18		82.2							18.4
140	16	19.24	19.03	30.58	24.55	31.9	39.7	108.5	150.0	16.27		80.3	47.3
140	34	34.80	33.42	52.80	46.98	27.5	30.9	120.0	284.0	34.08	10.4	89.0	55.5
140	49	50.60	51.17	72.30	66.92	27.4	29.6	99.3	498.0	49.42	9.0	92.6	55.0
140	68	62.84	64.55	98.12	92.30	28.1	29.9	125.0	650.0	68.23		94.1	54.2
140	77	77.90	82.63	111.15	105.85	29.1	30.5	85.0	900.0	76.50		95.3	51.6

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